

EXPEDITION WEEK STARTS SUNDAY, APRIL 3, AT 9 P.M. ET ON NAT GEO CHANNEL

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NATIONAL GEOGRAPHIC

THE GENIUS OF THE INCA

*New Discoveries Reveal How
They Forged a Mighty Empire*

**Crimea: A Jewel
in Two Crowns** 62

**The World's Most
Dangerous Volcano** 82

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Indomitable Snow Frogs 138

Machu Picchu, circa A.D. 1500

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NATIONAL GEOGRAPHIC

APRIL 2011 • VOL. 219 • NO. 4

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By Heather Pringle
- A Jewel in Two Crowns** **62** Crimea was once Russia's paradise. Now it belongs to Ukraine.
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By Paul Goldberger Photographs by Diane Cook and Len Jenschel
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By Mel White Photographs by Cyril Ruoso



CYRIL RUOSO, JH EDITORIAL/MINDEN PICTURES

Surface ice cannot deter an amorous frog. When spring comes to the Alps, the European common frog begins its search for a mate. Story on page 138.

NATIONAL GEOGRAPHIC

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Marriage Across Color Lines

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State Rock Stars

California was among the first to name—and the first to nearly disown—its state rock.

HISTORY

Polar Dogs and Ponies

An aeronautical chart of a New Zealand-to-Antarctica route honors four-legged explorers.

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Indian officials who stick out a hand for extra cash are chastened with a zero-rupee note.

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An ancient flier's 17-foot wingspan offers clues to how supersize birds flew.

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Annual grains feed the world, but they create perennial problems.

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On the Cover

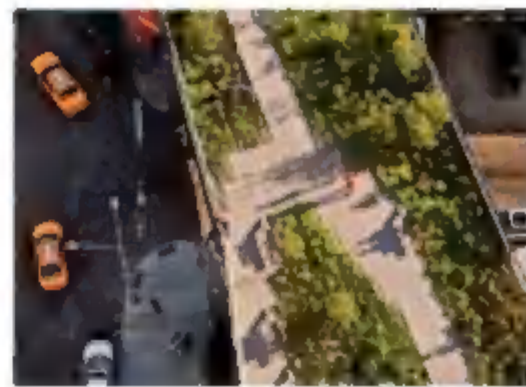
With 3-D data, experts helped shape this image of Machu Picchu, "lost city" of the Inca. The conical roof sits on the Temple of the Sun.

Art by Dylan Cole

Sources: Instituto Nacional de Cultura, Peru; Center for Advanced Spatial Technologies, University of Arkansas; Cotsen Institute of Archaeology, UCLA; Vincent R. Lee



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Online Adventures

Take a virtual walk on New York's High Line (above). Read Hiram Bingham's account of his Machu Picchu discovery. Learn more about a photographer's volcanic encounter.

DIANE COOK AND LEN JENSHEL



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The Nyiragongo expedition's cooking tent glows in the twilight on the rim of the volcano.

Few things on Earth rival the searing spectacle of a volcano. It's a force of nature most of us prefer to observe from a very long and safe distance.

Not volcanologist Ken Sims. He, along with *National Geographic* photographer Carsten Peter, could never be satisfied with anything less than standing on the edge of an erupting volcano. In fact, even standing on the edge of an erupting volcano wasn't enough for Sims. As part of his research, he rappelled down into the maw of Nyiragongo, a volcano in the Democratic Republic of the Congo, to gather fresh lava from a molten lake boiling at 1800° Fahrenheit.

Nyiragongo is one of the most active and least understood volcanoes in the world. It's also a threat to nearly a million residents of Goma, a city in this war-torn part of the world. Both Sims and Peter understood the nature of the geologic beast they were dealing with and were prepared to take risks. Sims wanted a sample of lava to help him predict eruptions. Peter wanted a photograph of Sims at work.

In this month's issue Peter documents the descent into the fiery heart of Nyiragongo. It was a quest, I'm proud to say, funded in part by a National Geographic Society grant. "It was a dream come true," Peter says of the experience. "You felt the pulse of the Earth through your body."



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"I have eaten two humans—
one was a man, the other a woman...
They taste the same."
Eating With Cannibals

Expedition Week

Beginning Sunday, April 3



Ben Franklin's Pirate Fleet



Lost Land of the Tiger

DEEP WITHIN THE JUNGLE of Papua New Guinea, explorer Piers Gibbon is on a quest to find out if cannibals still exist. Across the globe, paleontologist Jørn Hurum excavates Jurassic-period marine fossils from the remote islands of Svalbard, Norway. Theirs are just two of the adventures you'll see for the first time during Expedition Week, seven nights of new shows



debuting this month on the National Geographic Channel. Go high in the Himalaya with a team

of scientists as they search for Bhutan's hidden tigers. Then dive into the Irish Sea to discover whether it holds a pirate ship once commissioned by Benjamin Franklin. Is the Abominable Snowman more than just a myth? What gave Roman gladiators their extraordinary strength? Expedition Week covers it all, kicking off with *Eating With Cannibals*, airing April 3 at 9 p.m.

	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
9 p.m.	<i>Eating With Cannibals</i>	<i>Hunt for the Abominable Snowman</i>	<i>Gladiators Back From the Dead</i>	<i>Return of the Ghost Ship</i>	<i>Into Iceland's Volcano</i>	<i>Lost Land of the Tiger</i>	<i>Death of a Sea Monster</i>
10 p.m.	<i>Finding Jack the Ripper</i>	<i>Last Stand of the Templars</i>	<i>Egypt's Lost Rival</i>	<i>Ben Franklin's Pirate Fleet</i>	<i>Man vs. Volcano</i>	<i>Tiger Man of Africa</i>	<i>Secrets of the Hope Diamond</i>

For a full schedule of listings go to natgeotv.com.



Amami Rabbit (*Pentalagus furnessi*)

Size: Head and body length, 39.7 - 53 cm (15.6 - 20.9 inches); tail, 2 - 3.5 cm (0.8 - 1.4 inches) **Weight:** 2 - 2.9 kg (4.4 - 6.4 lbs) **Habitat:** Prefers dense forests; ranges from sea level to mountaintops **Surviving number:** Estimated at 2,000 - 4,800 on Amami-ohshima Island and 120 - 300 on Tokuno-shima Island



Photographed by Futoshi Hamada

WILDLIFE AS CANON SEES IT

Meet a true original. The Amami rabbit, found only on two isolated islands in southern Japan, has some of the most primitive characteristics found in living rabbits. Its ears, hind feet and tail are short, while its curved claws are formidably heavy and strong. It is also unusual in its method of communication, which involves both vocalizations and the beating of the ground with its hind limbs. At dusk, just before becoming active, it appears at the entrance to its

burrow and sends its calls ringing throughout the valleys. But bedeviled by introduced predators and suffering from severe habitat loss, this remarkable rabbit is in danger of meeting its untimely end.

As we see it, we can help make the world a better place. Raising awareness of endangered species is just one of the ways we at Canon are taking action—for the good of the planet we call home. Visit canon.com/environment to learn more.

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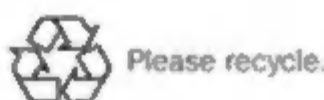
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December 2010

David and Solomon

It appears that in Peter Paul Rubens's 17th-century painting on the cover, David is wearing spandex biking shorts.

PAUL MCKELVEY
Cedar Park, Texas

This article took me back to the two summers I spent as a volunteer worker on two less controversial digs in Israel, Tel Michal and Tel Gerisa. I found it awesome to touch materials that had been touched by other human hands more than 2,400 years earlier. Less fascinating was observing how often certain archaeologists and professors seemed more concerned with preserving their own interpretations of finds than with the honest search for the truth—exactly the sort of disputes described in your article. One thing we were lectured about is that absence of evidence is not evidence of absence. Considering the utter destruction of Jerusalem by the Babylonians in 586 B.C. and by the Romans in A.D. 70, it is a wonder that so many things that fit into biblical narratives have been discovered and continue to be discovered.

DEAN C. NELSON
St. Paul, Minnesota

It matters not at all whether David's city was mud or marble, or whether it existed at all. It is immortal, transforming, and magnificent because the city lives in words that have triumphed through 2,500 years. Of course David slew Goliath. Davids slay Goliaths every day. The Bible records eternal principles of the human condition. Its parables and psalms spring from our common experience of mortal life. Dig away, skeptics and believers alike. The truths of the Bible are intuitive, precious, and unimpeachable—bones or no bones.

FRANK AND AUDREY CARROLL
Custer, South Dakota

Salmon or Gold

The proposed mine in the Bristol Bay area is another environmental nightmare in the planning stages. The Pebble Partnership is pledging to maintain the integrity and safety of impoundment ponds in perpetuity. How long is that? It's absurd. BP said its operations were safe too. Corporations always say that, but Superfund sites around the country are testament to the capacity of industry to dodge responsibility. The planet is finite. If those deposits of gold and copper weren't there, we'd do without them. Better to live within our means now and save what we have left. Is this planet a garden to tend or a sponge to squeeze?

MOSS HENRY
Santa Rosa, California

As you stated, mine owners promise jobs and an infusion of money. Mine owners have promised the same things for years, but delivery has been a different matter. The results

have not varied: short-term jobs, short-term money, and virtually permanent environmental damage.

MARTY BANKHEAD
Lake Oswego, Oregon

As a former Alaska commercial fisherman (never in Bristol Bay for salmon, but in the area for more than 20 years in other fisheries), I have extensive experience with the natural glory and bounty there. The fragility of the sub-Arctic and tundra environments is well known. Pebble mine is centered in the middle of the headwaters of not only Upper Talarik Creek, which leads into Iliamna Lake and the Kvichak River, but also the Koktuli, Mulchatna, and Nushagak River systems. Between these two systems, with one spill, the potential exists to wipe out the single-largest pristine salmon, trout, and steelhead environment in the world. This cannot be allowed to occur. Once it is gone, it can never be replaced. I am not a rabid environmentalist by any stretch of the imagination, but my vote is "Hands off!"

PHILLIP M. (MIKE) SNOWDEN
Snohomish, Washington

Corrections

DECEMBER 2010: GAUDI POSTER
The Organic Windows art on the "Design by Nature" side does not show a marine diatom, as labeled. What is illustrated is another tiny marine animal called a spherical radiolarian. On the time line, the correct date of the nave's completion is 2000.

Email ngsforum@ngm.com
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Very high triglycerides is a medical term for something serious:

TOO MUCH FAT IN YOUR BLOOD.

Ask your doctor about the FDA-approved medication made from omega-3 fish oil: **LOVAZA**

If you have high cholesterol, diabetes or are overweight you may also have very high triglycerides (≥ 500 mg/dL), which is a serious medical condition. LOVAZA, along with diet, has been clinically proven to lower very high triglycerides in adult patients. Individual results may vary. LOVAZA has not been shown to prevent heart attacks or strokes. It's purified. It's concentrated. And you can't get it at a health food store. Ask your doctor about LOVAZA—the prescription that starts in the sea.

LOVAZA is used along with a low-fat and low-cholesterol diet to lower very high triglycerides (fats) in your blood. Before taking LOVAZA, talk to your healthcare provider about how you can lower high blood fats by: losing weight if you are overweight, increasing physical exercise, lowering alcohol use, treating diseases such as diabetes and low thyroid (hypothyroidism), adjusting the dose or changing other medicines that raise triglyceride levels such as certain blood pressure medicines and estrogens.

Important Safety Information for LOVAZA

LOVAZA, along with diet, helps to lower very high triglycerides (≥ 500 mg/dL) in adult patients. Tell your doctor if you are allergic to fish or shellfish or if LOVAZA may not be right for you. Talk to your doctor about any medical conditions you have and any medications you are taking, especially those that may increase your risk of bleeding. In some patients, LDL (bad) cholesterol may increase. Your healthcare provider should do blood tests before and during treatment with LOVAZA to check your cholesterol and triglyceride levels. If you have liver disease, you may require additional monitoring. Possible side effects include burping, infection, flu-like symptoms, upset stomach and change in sense of taste. How supplied: 1-gram capsule

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Capsule shown not actual size

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LOVAZA® (lō-vā-ză)
(omega-3-acid ethyl esters) Capsules

LOVAZA®
omega-3-acid ethyl esters

Read the Patient Information that comes with LOVAZA before you start taking it, and each time you get a refill. There may be new information. This leaflet summarizes the most important information about LOVAZA and does not take the place of talking with your doctor about your condition or treatment.

What is LOVAZA?

LOVAZA is a prescription medicine, called a lipid-regulating medicine, for adults. LOVAZA is made of omega-3 fatty acids from oils of fish, such as salmon and mackerel. Omega-3 fatty acids are substances that your body needs but cannot produce itself.

LOVAZA is used along with a low-fat and low-cholesterol diet to lower very high triglycerides (fats) in your blood. Before taking LOVAZA, talk to your healthcare provider about how you can lower high blood fats by:

- losing weight, if you are overweight
- increasing physical exercise
- lowering alcohol use
- treating diseases such as diabetes and low thyroid (hypothyroidism)
- adjusting the dose or changing other medicines that raise triglyceride levels such as certain blood pressure medicines and estrogens

Treatment with LOVAZA has not been shown to prevent heart attacks or strokes.

LOVAZA has not been studied in children under the age of 18 years.

Who should NOT take LOVAZA?

Do not take LOVAZA if you:

- **are allergic to LOVAZA or any of its ingredients.**

What should I tell my doctor before taking LOVAZA?

Tell your doctor about all of your medical conditions, including if you:

- drink more than 2 glasses of alcohol daily.
- have diabetes.
- have a thyroid problem called hypothyroidism.
- have a liver problem.
- have a pancreas problem.
- are allergic to fish and/or shellfish. LOVAZA may not be right for you.
- are pregnant, or planning to become pregnant. It is not known if LOVAZA can harm your unborn baby.
- are breastfeeding. It is not known if LOVAZA passes into your milk and if it can harm your baby.

Tell your doctor about all the medicines you take, including prescription and non-prescription medicine, vitamins, and herbal supplements. LOVAZA and certain other medicines can interact. Especially tell your doctor if you take medicines that affect clotting such as anticoagulants or blood thinners. Examples of these medicines include aspirin, nonsteroidal anti-inflammatory agents (NSAIDs), warfarin, coumarin, and clopidogrel (PLAVIX®).

How should I take LOVAZA?

- Take LOVAZA exactly as prescribed. Do not change your dose or stop LOVAZA without talking to your doctor.
- Your doctor should start you on a low-fat and low-cholesterol diet before giving you LOVAZA. Stay on this low-fat and low-cholesterol diet while taking LOVAZA.
- Your doctor should do blood tests to check your triglyceride and cholesterol levels during treatment with LOVAZA.
- If you have liver disease, your doctor should do blood tests to check your liver function during treatment with LOVAZA.

What are the possible side effects of LOVAZA?

The most common side effects with LOVAZA are burping, infection, flu symptoms, upset stomach, and a change in your sense of taste.

LOVAZA may affect certain blood tests. ■ may change:

- one of the tests to check liver function (ALT)
- one of the tests to measure cholesterol levels (LDL-C)

Talk to your doctor if you have side effects that bother you or that will not go away.

These are not all the side effects with LOVAZA. For more information, ask your doctor or pharmacist.

What are the ingredients in LOVAZA?

Active Ingredient:

Omega-3-acid ethyl esters

Inactive Ingredients: Gelatin, glycerol, purified water, alpha-tocopherol (in soybean oil)

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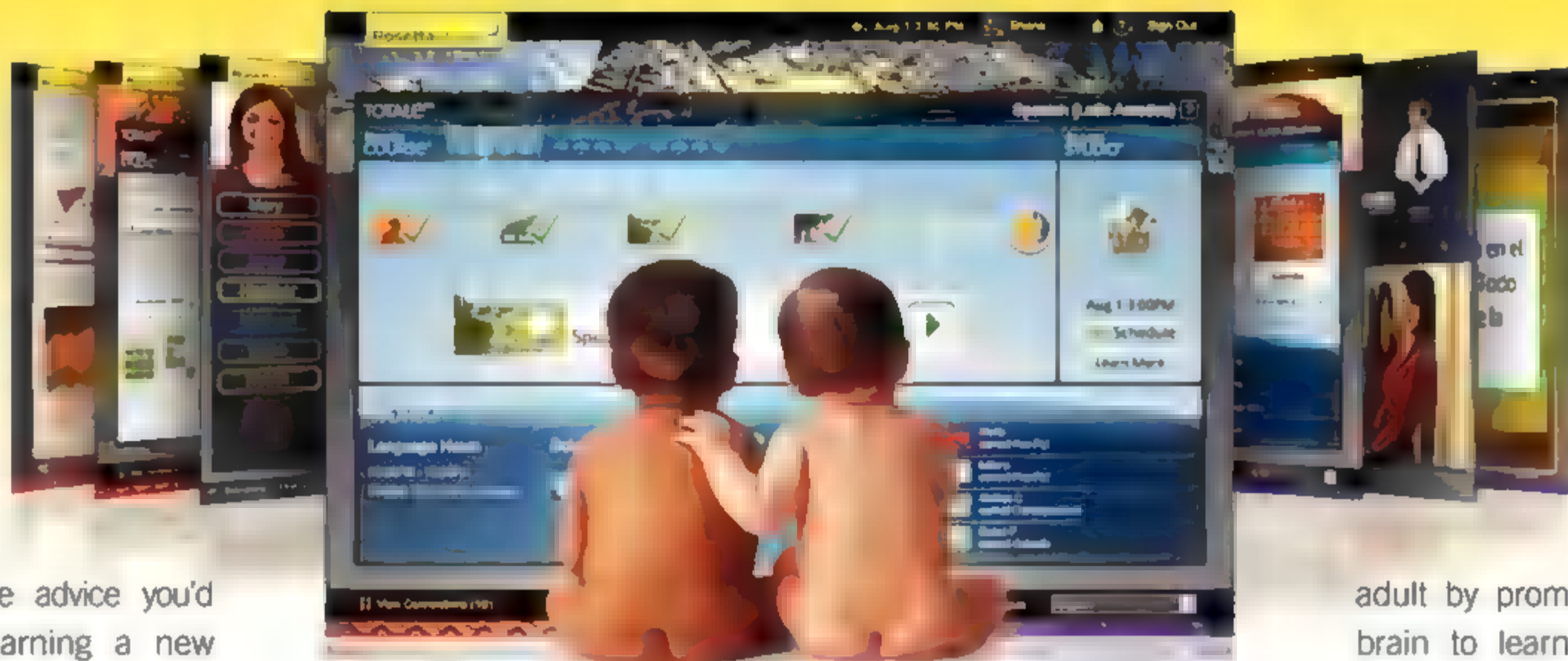
GlaxoSmithKline

GlaxoSmithKline

Research Triangle Park, NC 27709

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It's not the advice you'd expect. Learning a new language seems formidable, as we recall from years of combat with grammar and translations in school. Yet infants begin at birth. They communicate at eighteen months and speak the language fluently before they go to school. And they never battle translations or grammar explanations along the way. Born into a veritable language jamboree, children figure out language purely from the sounds, objects and interactions around them. Their senses fire up neural circuits that send the stimuli to different language areas in the brain. Meanings fuse to words. Words string into structures. And language erupts.

What's the fastest way to learn a language? **ACT LIKE A BABY.**

adult by prompting your brain to learn language the way it's wired to learn language: by complete immersion. Our award-winning, computer-based method does just that. Dynamic Immersion™ unlocks the innate language-learning ability you acquired before birth and mastered as a child. By recreating the immersion context in which you learned your first language, you understand, speak, read and write your new language with confidence and accuracy from the beginning — without translations and explanations. At every step and in every skill, you receive instant, actionable feedback, including speech recognition and analysis technologies that prepare you for everyday conversations. And Adaptive Recall™ brings back material just when you need it to reinforce and perfect your learning.

Three characteristics of the child's language-learning process are crucial for success:

First, and most importantly, a child's natural language-learning ability emerges only in a speech-soaked, immersion environment free of translations and explanations of grammar. Second, a child's language learning is dramatically accelerated by constant feedback from family and friends. Positive correction and persistent reinforcement nurture the child's language and language skills into full communicative expression. Third, children learn through play, whether it's the arm-waving balancing act that announces their first step or the spluttering preamble to their first words. All the conversational chatter skittering through young children's play with parents and playmates — "...what's this..." "...clap, clap your hands..." "...my ball..." — helps children develop language skills that connect them to the world.

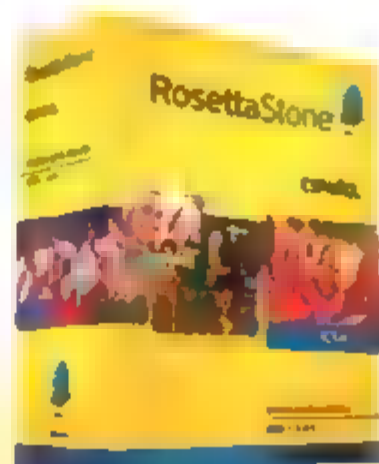
Adults possess this same powerful language-learning ability that orchestrated our language success as children.

Sadly, our clashes with vocabulary drills and grammar explanations force us to conclude it's hopeless. We simply don't have "the language-learning gene." At Rosetta Stone, we know otherwise. You can recover your native language-learning ability as an

adult by prompting your brain to learn language the way it's wired to learn language: by complete immersion. Our award-winning, computer-based method does just that. Dynamic Immersion™ unlocks the innate language-learning ability you acquired before birth and mastered as a child. By recreating the immersion context in which you learned your first language, you understand, speak, read and write your new language with confidence and accuracy from the beginning — without translations and explanations. At every step and in every skill, you receive instant, actionable feedback, including speech recognition and analysis technologies that prepare you for everyday conversations. And Adaptive Recall™ brings back material just when you need it to reinforce and perfect your learning.

Every act of learning is an act of play for children and there's no reason it should be different for learners of any age.

With Rosetta Stone™ programs, you rediscover the joy of learning language. Clever, puzzle-like activities produce sudden "Aha!" moments and astonishing language discoveries. Your "language brain" remembers. We see it all the time. A slow smile sneaks across the learner's face after just a few screens. It's a smile of recognition, as though the brain suddenly recalls what it was like to learn language as a child, as though it realizes, "Aha! I've done this before." Act like a baby? You bet. Visit our website and find out how you can reactivate your own innate, language-learning ability with Rosetta Stone. It's the fastest way to learn a language. Guaranteed.*



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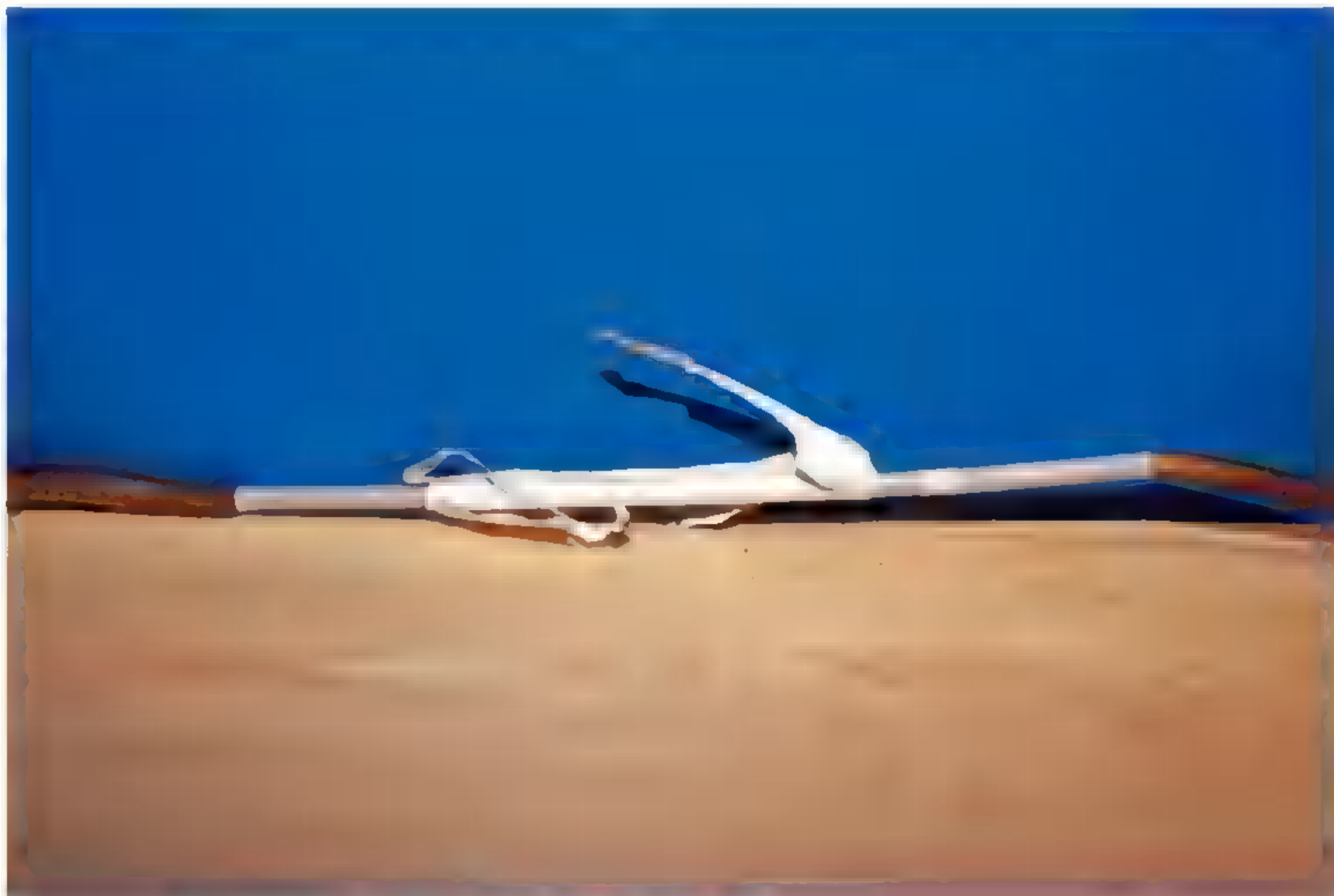
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EDITORS' CHOICE **Ouseph Paul Chalakal** Dubai, United Arab Emirates

"This happened on my office desk without me knowing it," says Chalakal, 57. When a thirsty root from his potted plant found an obstacle in its path, he says, it passed right through the plastic straw.



READERS' CHOICE

Tania Lee Crow
Cornwall, England

Three months after a cyclone tore through the South Pacific's Cook Islands, Crow visited the atoll of Aitutaki. From the backseat of a moving car she saw this chicken perched on a palm tree's sagging frond. "It was such an unusual, comic sight," she says. "I asked the driver to slow down and took the shot out the window as we drove by."

This page features two photographs: one chosen by our editors and one chosen by our readers by online voting. For more information, go to ngm.com/yourshot.

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VISIONS OF EARTH



Germany A boxy Trabant scoots past other Cold War vestiges at Checkpoint Charlie, where the image of a U.S. soldier looks into former East Berlin. A Russian soldier on the pole's reverse faces what was the American side of the crossing.

PHOTO ANDREW MCLEISH, LIGHTMEDIATION



Namibia In a scene stolen from a dream, a house succumbs to sand in Kolmanskop, once a thriving settlement for diamond miners. Winds have helped desert dunes reclaim the site, abandoned for more than 50 years.





Mongolia East meets West on the frigid steppe as a teenager clad in a traditional *del* practices basketball near Batsumber village. Playing courts dot rural areas and cities alike as the game catches on with the nation's youth.



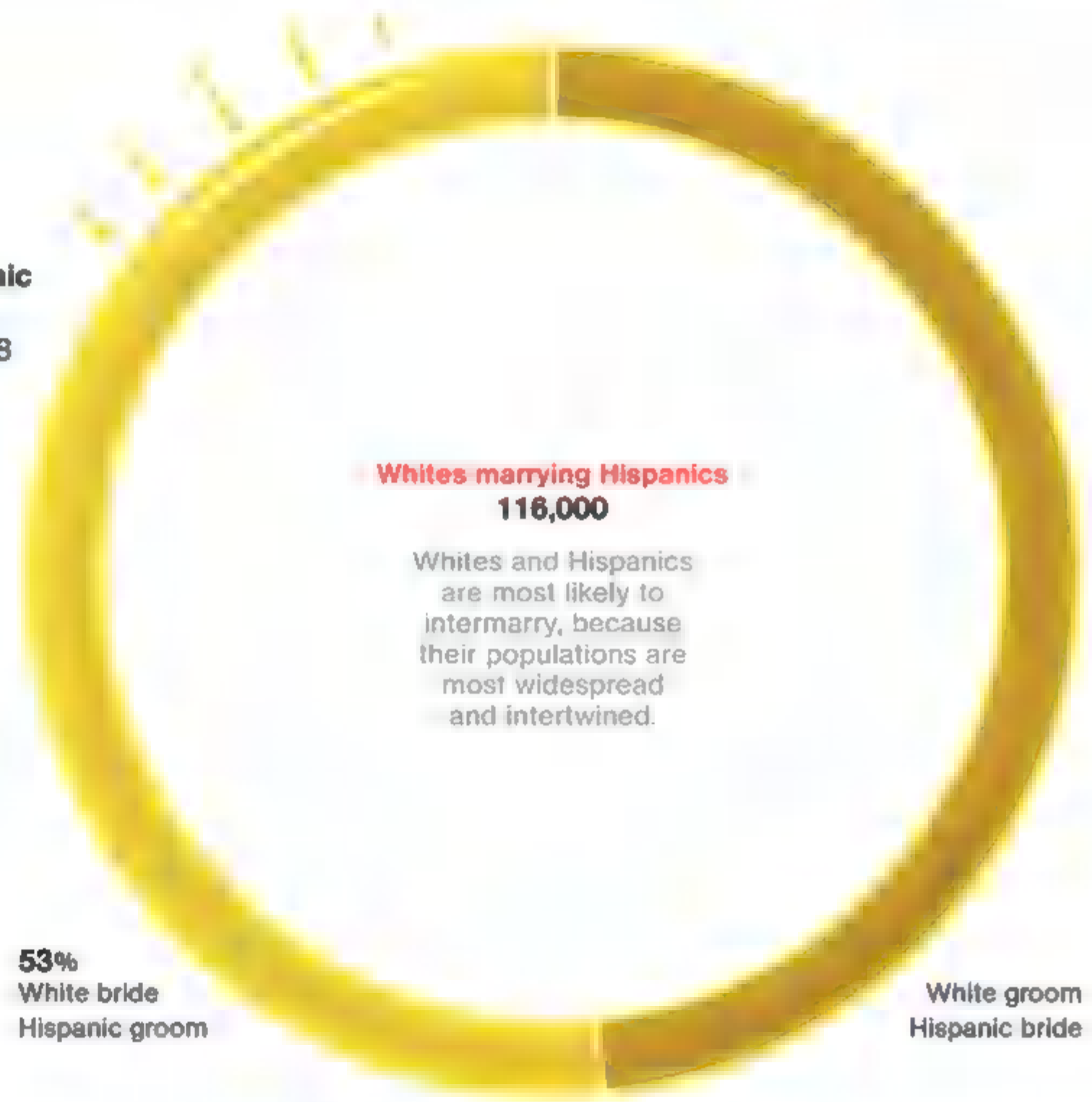
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PHOTO BRUNO MORANDI, LIGHTMEDIATION



POPULATION

Racial and ethnic intermarriages in the U.S., 2008



Marrying Out

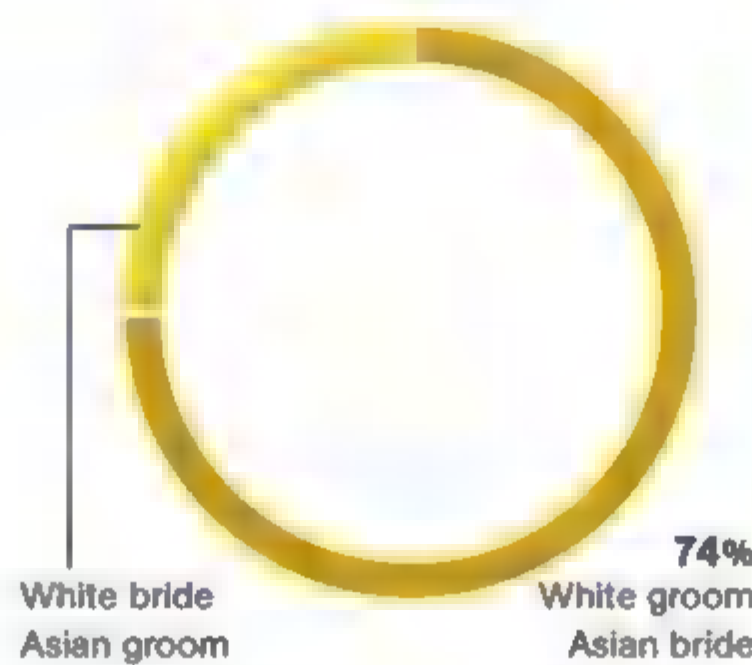
Barack Obama made history when he became America's first black President. His parents were pioneers as well: When they wed in

7 SEVEN BILLION 1961, interracial unions were illegal in more than a dozen states and fewer than one in 1,000 new U.S. marriages involved black and white partners. Now it's one in 60.

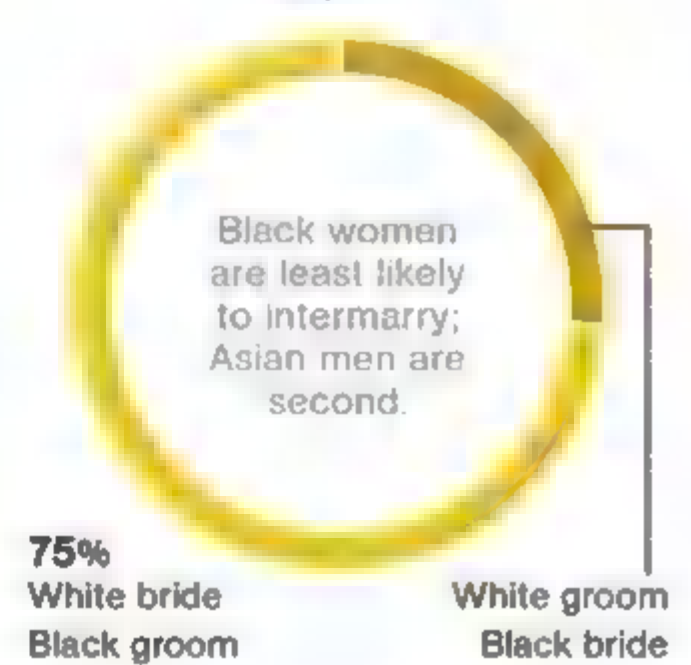
A recent Pew Research Center analysis shows the trend has spread across races and ethnicities, with mixed unions reaching a record 14.6 percent of new marriages in 2008. The numbers reflect an immigration-fueled rise in the country's minority populations, along with growing acceptance of mixed couples. (Antimiscegenation laws ended in 1967 when the Supreme Court struck down Virginia's ban.) Though immigrants do not tend to intermarry, their children do, says Pew senior demographer Jeff Passel.

Regionally, the West, with its high percentage of Hispanics and Asians, sees the most intermixing. Notes Passel: "As these couples have children, there will be more fuzziness in how race and ethnic groups are defined." —Luna Shyr

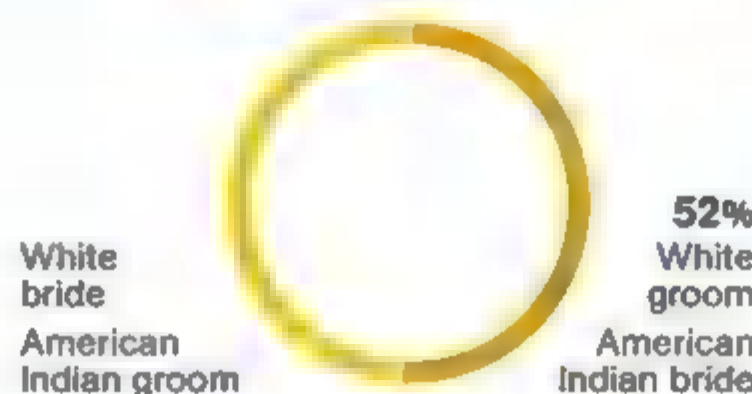
Whites + Asians
43,100



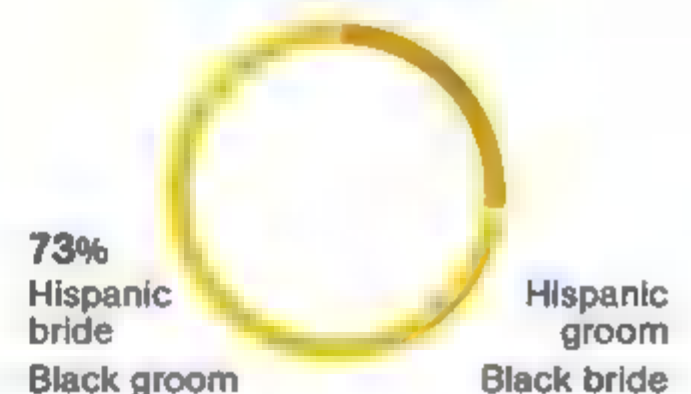
Whites + Blacks
32,300



Whites + American Indians*
14,600



Hispanics + Blacks
12,600



Hispanics + Asians
6,700



Blacks + Asians
3,700



*MARRIAGES BETWEEN AMERICAN INDIANS AND BLACKS, HISPANICS, AND ASIANS TOO FEW TO SHOW GRAPHIC: NIGEL HOLMES. SOURCE: PEW RESEARCH CENTER

ARE YOU KIDDING YOURSELF?



YOU THINK YOU'VE GOT PLENTY OF TIME TO LOWER YOUR HIGH CHOLESTEROL, BUT EVERY 34 SECONDS IN THE U.S. SOMEONE HAS A HEART ATTACK.

If you've been waiting to lower your high cholesterol, stop kidding yourself. High cholesterol is a significant risk factor for heart attacks.

When healthy diet and exercise are not enough, adding Lipitor may help. Along with diet:

- Lipitor has been shown to lower bad cholesterol 39% to 60% (average effect depending on dose).
- Lipitor is FDA-approved to reduce the risk of heart attack and stroke in patients who have heart disease or risk factors for heart disease. These risk factors include smoking, age, family history of early heart disease, high blood pressure and low good cholesterol.

Lipitor is backed by over 18 years of research.

Talk to your doctor about your risk and about Lipitor. Learn more at lipitor.com or call 1-888-LIPITOR (1-888-547-4867).

Please see additional important information on next page.

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IMPORTANT SAFETY INFORMATION: LIPITOR is not for everyone. It is not for those with liver problems. And it is not for women who are nursing, pregnant or may become pregnant.

If you take LIPITOR, tell your doctor if you feel any new muscle pain or weakness. This could be a sign of rare but serious muscle side effects. Tell your doctor about all medications you take. This may help avoid serious drug interactions. Your doctor should do blood tests to check your liver function before and during treatment and may adjust your dose.

Common side effects are diarrhea, upset stomach, muscle and joint pain, and changes in some blood tests.

INDICATION:

LIPITOR is a prescription medicine that is used along with a low-fat diet. It lowers the LDL ("bad" cholesterol) and triglycerides in your blood. It can raise your HDL ("good" cholesterol) as well. LIPITOR can lower the risk for heart attack, stroke, certain types of heart surgery, and chest pain in patients who have heart disease or risk factors for heart disease such as age, smoking, high blood pressure, low HDL, or family history of early heart disease.

LIPITOR can lower the risk for heart attack or stroke in patients with diabetes and risk factors such as diabetic eye or kidney problems, smoking or high blood pressure.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch or call 1-800-FDA-1088.



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IMPORTANT FACTS



(LIP-ih-tore)

LOWERING YOUR HIGH CHOLESTEROL

High cholesterol is more than just a number, it's a risk factor that should not be ignored. If your doctor said you have high cholesterol, you may be at an increased risk for heart attack and stroke. But the good news is, you can take steps to lower your cholesterol.

With the help of your doctor and a cholesterol-lowering medicine like LIPITOR, along with diet and exercise, you could be on your way to lowering your cholesterol.

Ready to start eating right and exercising more? Talk to your doctor and visit the American Heart Association at www.americanheart.org.

WHO IS LIPITOR FOR?

Who can take LIPITOR:

- People who cannot lower their cholesterol enough with diet and exercise
- Adults and children over 10

Who should NOT take LIPITOR:

- Women who are pregnant, may be pregnant, or may become pregnant. LIPITOR may harm your unborn baby. If you become pregnant, stop LIPITOR and call your doctor right away.
- Women who are breast-feeding. LIPITOR can pass into your breast milk and may harm your baby.
- People with liver problems
- People allergic to anything in LIPITOR

BEFORE YOU START LIPITOR

Tell your doctor:

- About all medications you take, including prescriptions, over-the-counter medications, vitamins, and herbal supplements
- If you have muscle aches or weakness
- If you drink more than 2 alcoholic drinks a day
- If you have diabetes or kidney problems
- If you have a thyroid problem

ABOUT LIPITOR

LIPITOR is a prescription medicine. Along with diet and exercise, it lowers "bad" cholesterol in your blood. It can also raise "good" cholesterol (HDL-C).

LIPITOR can lower the risk of heart attack, stroke, certain types of heart surgery, and chest pain in patients who have heart disease or risk factors for heart disease such as:

- age, smoking, high blood pressure, low HDL-C, family history of early heart disease

LIPITOR can lower the risk of heart attack or stroke in patients with diabetes and risk factors such as diabetic eye or kidney problems, smoking, or high blood pressure.

POSSIBLE SIDE EFFECTS OF LIPITOR

Serious side effects in a small number of people:

- **Muscle problems** that can lead to kidney problems, including kidney failure. Your chance for muscle problems is higher if you take certain other medicines with LIPITOR.
 - **Liver problems.** Your doctor may do blood tests to check your liver before you start LIPITOR and while you are taking it.
- Call your doctor right away if you have:**
- Unexplained muscle weakness or pain, especially if you have a fever or feel very tired
 - Allergic reactions including swelling of the face, lips, tongue, and/or throat that may cause difficulty in breathing or swallowing which may require treatment right away
 - Nausea, vomiting, or stomach pain
 - Brown or dark-colored urine
 - Feeling more tired than usual
 - Your skin and the whites of your eyes turn yellow
 - Allergic skin reactions

Common side effects of LIPITOR are:

- Diarrhea
- Muscle and joint pain
- Upset stomach
- Changes in some blood tests

HOW TO TAKE LIPITOR

Do:

- Take LIPITOR as prescribed by your doctor.
- Try to eat heart-healthy foods while you take LIPITOR.
- Take LIPITOR at any time of day, with or without food.
- If you miss a dose, take it as soon as you remember. But if it has been more than 12 hours since your missed dose, wait. Take the next dose at your regular time.

Don't:

- Do not change or stop your dose before talking to your doctor.
- Do not start new medicines before talking to your doctor.
- Do not give your LIPITOR to other people. It may harm them even if your problems are the same.
- Do not break the tablet.

NEED MORE INFORMATION?

- Ask your doctor or health care provider.
- Talk to your pharmacist.
- Go to www.lipitor.com or call 1-888-LIPITOR.




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The "ring that everybody wants" won't wait forever. Call today to claim your very own version of the "Most Desired Ring in the World" for the unbelievable price of only \$99! Our version features an impressive 2½-carat lab-created sapphire oval, prong-set in a band of sterling silver. The regal blue beauty is surrounded by a sunburst of 14 lab-created DiamondAura® rounds that sparkle with even more clarity and fire than mined diamonds.

The breakthrough science behind "happily ever after." The difference between our lab-created gemstone and the original royal sapphire is that the natural sapphire has flaws called inclusions.

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sapphires that have no inclusions because the heat and pressure are controlled in the laboratory. The result is that scientifically grown stones look superior to most mined stones.

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A selection of state rocks and stones reflects mineral wealth in the U.S.

State Rock Stars

In 1965 serpentine became one of America's first state rocks. A California bill to oust it last year, based on its traces of asbestos, did not pass. But it did raise the question: Why do some states have official rocks?

Experts say geology and economy are key. States rich in mineral deposits—and vested industries—anooint a rock or stone to promote pride and profit. Some share one. Those stuck without? Hard luck, indeed. —Jeremy Berlin

- 1 Serpentine California
- 2 Geode Iowa
- 3 Bauxite Arkansas
- 4 Slate Vermont
- 5 Thunder egg Oregon
- 6 Red granite Wisconsin
- 7 Agate Kentucky, Nebraska
- 8 Limestone Tennessee
- 9 Petoskey stone Michigan
- 10 Cumberlandite Rhode Island
- 11 Barite rose Oklahoma
- 12 Mozarkite Missouri
- 13 Roxbury puddingstone Massachusetts
- 14 Marble Alabama, Colorado, Vermont
- 15 Coal Utah, West Virginia
- 16 Sandstone Nevada
- 17 Granite New Hampshire, North Carolina, Vermont



WHERE GODS BECOME MOUNTAINS

The Inca took giant blocks of stone and brought them to life, raising them high up to heavens. There, he made his home with magnificent gardens and walls covered in gold. At the Sun's Gate the clouds part to unveil a mystery that still today remains alive in the midst of one of the most majestic masterpieces created ever by man. This place exists. You can see it, feel it

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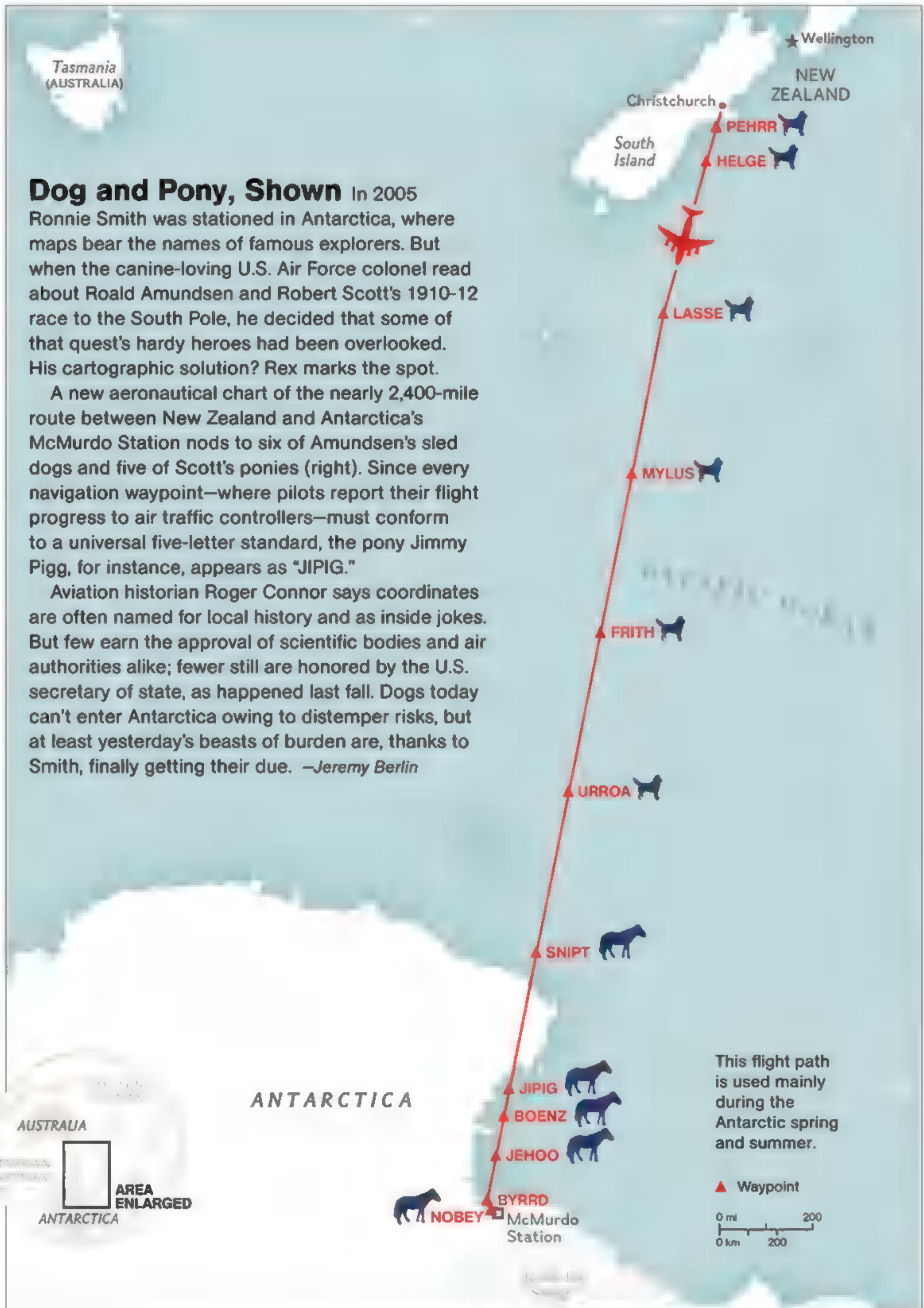
HISTORY

Dog and Pony, Shown

In 2005 Ronnie Smith was stationed in Antarctica, where maps bear the names of famous explorers. But when the canine-loving U.S. Air Force colonel read about Roald Amundsen and Robert Scott's 1910-12 race to the South Pole, he decided that some of that quest's hardy heroes had been overlooked. His cartographic solution? Rex marks the spot.

A new aeronautical chart of the nearly 2,400-mile route between New Zealand and Antarctica's McMurdo Station nods to six of Amundsen's sled dogs and five of Scott's ponies (right). Since every navigation waypoint—where pilots report their flight progress to air traffic controllers—must conform to a universal five-letter standard, the pony Jimmy Pigg, for instance, appears as "JIPIG."

Aviation historian Roger Connor says coordinates are often named for local history and as inside jokes. But few earn the approval of scientific bodies and air authorities alike; fewer still are honored by the U.S. secretary of state, as happened last fall. Dogs today can't enter Antarctica owing to distemper risks, but at least yesterday's beasts of burden are, thanks to Smith, finally getting their due. —Jeremy Berlin



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Designed to look like standard Indian currency, zero-rupee notes are larger and printed on thicker paper. That discourages folding, which is a common way for bribes to be passed.

Bribe-busting Bill In India, where corruption costs the public and private sectors millions of dollars a year, demands for petty bribes are frequently signaled in code: “Take care of me” or, for a two-note handout, “Make Gandhi smile twice.” Illegal demands by police and bureaucrats are “deeply ingrained in the culture,” says anticorruption crusader Vijay Anand, and are “taken as the norm.”

But 5th Pillar, Anand’s grassroots citizens group, is trying to create a new norm—by printing and passing out notes worth nothing at all (above). Since 2007, 5th Pillar has distributed 1.3 million zero-rupee bills. People give them as

a polite protest to officials trying to squeeze extra payment for routine services like issuing driver’s licenses or loans. The effect has been to shame or scare some public servants—who can go to jail if they’re caught—into honest behavior. The zero-rupee note, says anticorruption researcher Fumiko Nagano, emboldens people to assert their rights, because when they’re backed up by 5th Pillar, “they realize they are not alone.”

Nor is India. Zero-currency notes are spreading to help fight corruption in Mexico and Nepal as well—an affirmation of nonviolent resistance that would surely have made Gandhi smile for real. —Hannah Bloch

For arthritis patients, it's simple physics:

A body in motion...tends to stay in motion.



Celebrex can help relieve arthritis pain... so you can keep moving.

It's simple physics — a body in motion tends to stay in motion. Staying active can actually relieve arthritis symptoms. But if you have arthritis, staying active can be difficult.

That's why you should talk with your doctor about treatment options, like prescription Celebrex.

- Just one 200mg Celebrex a day can provide 24-hour relief for many with arthritis pain and inflammation.* Relief that can help your body stay in motion.
- In clinical studies with osteoarthritis patients, Celebrex is proven to improve pain, stiffness and daily physical function.
- Celebrex is not a narcotic.

Important Safety Information:

Like all prescription NSAIDs, CELEBREX may increase the chance of heart attack or stroke that can lead to death. This chance increases if you have heart disease or risk factors for it, such as high blood pressure or when NSAIDs are taken for long periods.

CELEBREX should not be used right before or after certain heart surgeries.

Serious skin reactions, or stomach and intestine problems such as bleeding and ulcers, can occur without warning and may cause death. Patients taking aspirin and the elderly are at increased risk for stomach bleeding and ulcers.

When it comes to relieving arthritis pain, you and your doctor need to balance the benefits with the risks — and find the right treatment for you.

So ask your doctor about Celebrex. It could be an important step towards keeping *your* body in motion.

Visit celebrex.com

or call 1-888-CELEBREX for more information.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit fda.gov/medwatch or call 1-800-FDA-1088.

*Individual results may vary.

Tell your doctor if you have: a history of ulcers or bleeding in the stomach or intestines; high blood pressure or heart failure; or kidney or liver problems.

CELEBREX should not be taken in late pregnancy.

Do not take CELEBREX if you've had an asthma attack, hives, or other allergic reactions to aspirin, any other NSAID medicine or certain drugs called sulfonamides.

Life threatening allergic reactions can occur with CELEBREX. Get help right away if you've had swelling of the face or throat or trouble breathing.

Prescription CELEBREX should be used exactly as prescribed at the lowest dose possible and for the shortest time needed.

See the Medication Guide on the next page for important information about Celebrex and other prescription NSAIDs.



Uninsured? Need help paying for Pfizer medicines?

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CELEBREX
(CELECOXIB CAPSULES) 100mg
200mg

For a body in motion

CELEBREX®
(celecoxib capsules)

Medication Guide

for Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)

(See the end of this Medication Guide for a list of prescription NSAID medicines.)

What is the most important information I should know about medicines called Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)?

NSAID medicines may increase the chance of a heart attack or stroke that can lead to death.

This chance increases:

- with longer use of NSAID medicines
- in people who have heart disease

NSAID medicines should never be used right before ■ after a heart surgery called a “coronary artery bypass graft (CABG).”

NSAID medicines can cause ulcers and bleeding in the stomach and intestines at any time during treatment. Ulcers and bleeding:

- can happen without warning symptoms
- may cause death

The chance of a person getting an ulcer or bleeding increases with:

- taking medicines called “corticosteroids” and “anticoagulants”
- longer use
- smoking
- drinking alcohol
- older age
- having poor health

NSAID medicines should only ■ used:

- exactly as prescribed
- at the lowest dose possible for your treatment
- for the shortest time needed

What are Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)?

NSAID medicines are used to treat pain and redness, swelling, and heat (inflammation) from medical conditions such as:

- different types of arthritis
- menstrual cramps and other types of short-term pain

Who should not take a Non-Steroidal Anti-Inflammatory Drug (NSAID)?

Do not take an NSAID medicine:

- if you had an asthma attack, hives, or other allergic reaction with aspirin or any other NSAID medicine
- for pain right before or after heart bypass surgery

Tell your healthcare provider:

- about all of your medical conditions.
- about all of the medicines you take. NSAIDs and some other medicines can interact with each other and cause serious side effects. **Keep a list of your medicines to show to your healthcare provider and pharmacist.**
- if you are pregnant. **NSAID medicines should not be used by pregnant women late in their pregnancy.**
- if you are breastfeeding. **Talk to your doctor.**

What are the possible side effects of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)?

Serious side effects include:

- heart attack
- stroke
- high blood pressure
- heart failure from body swelling (fluid retention)
- kidney problems including kidney failure
- bleeding and ulcers in the stomach and intestine
- low red blood cells (anemia)
- life-threatening skin reactions
- life-threatening allergic reactions
- liver problems including liver failure
- asthma attacks in people who have asthma

Other side effects include:

- stomach pain
- constipation
- diarrhea
- gas
- heartburn
- nausea
- vomiting
- dizziness

Get emergency help right away if you have any of the following symptoms:

- shortness of breath or trouble breathing
- chest pain
- weakness in one part or side of your body
- slurred speech
- swelling of the face or throat

Stop your NSAID medicine and call your healthcare provider right away if you have any of the following symptoms:

- nausea
- more tired or weaker than usual
- itching
- your skin or eyes look yellow
- stomach pain
- flu-like symptoms
- vomit blood
- there is blood in your bowel movement or it is black and sticky like tar
- skin rash or blisters with fever
- unusual weight gain
- swelling of the arms and legs, hands and feet

These are not ■ the side effects with NSAID medicines. Talk to your healthcare provider or pharmacist for more information about NSAID medicines.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

Other information about Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)

- Aspirin is an NSAID medicine but it does not increase the chance of a heart attack. Aspirin can cause bleeding in the brain, stomach, and intestines. Aspirin can also cause ulcers in the stomach and intestines.
- Some of these NSAID medicines are sold in lower doses without a prescription (over-the-counter). Talk to your healthcare provider before using over-the-counter NSAIDs for more than 10 days.

NSAID medicines that need a prescription

Generic Name	Tradename
Celecoxib	Celebrex
Diclofenac	Cataflam, Voltaren, Arthrotec (combined with misoprostol)
Diflunisal	Dolobid
Etodolac	Lodine, Lodine XL
Fenoprofen	Nalfon, Nalfon 200
Flurbiprofen	Ansaid
Ibuprofen	Motrin, Tab-Profen, Vicoprofen* (combined with hydrocodone), Combunox (combined with oxycodone)
Indomethacin	Indocin, Indocin SR, Indo-Lemmon, Indomethagan
Ketoprofen	Oruvail
Ketorolac	Toradol
Mefenamic Acid	Ponstel
Meloxicam	Mobic
Nabumetone	Relafen
Naproxen	Naprosyn, Anaprox, Anaprox DS, EC-Naproxyn, Naprelan, Naprapac (copackaged with lansoprazole)
Oxaprozin	Daypro
Piroxicam	Feldene
Sulindac	Clinoril
Tolmetin	Tolectin, Tolectin DS, Tolectin 600

*Vicoprofen contains the same dose of ibuprofen as over-the-counter (OTC) NSAIDs, and is usually used for less than 10 days to treat pain. The OTC NSAID label warns that long term continuous use may increase the risk of heart attack or stroke.

This Medication Guide has been approved by the U.S. Food and Drug Administration.

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NATIONAL GEOGRAPHIC
ACTIVITY REPORT

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desert flower

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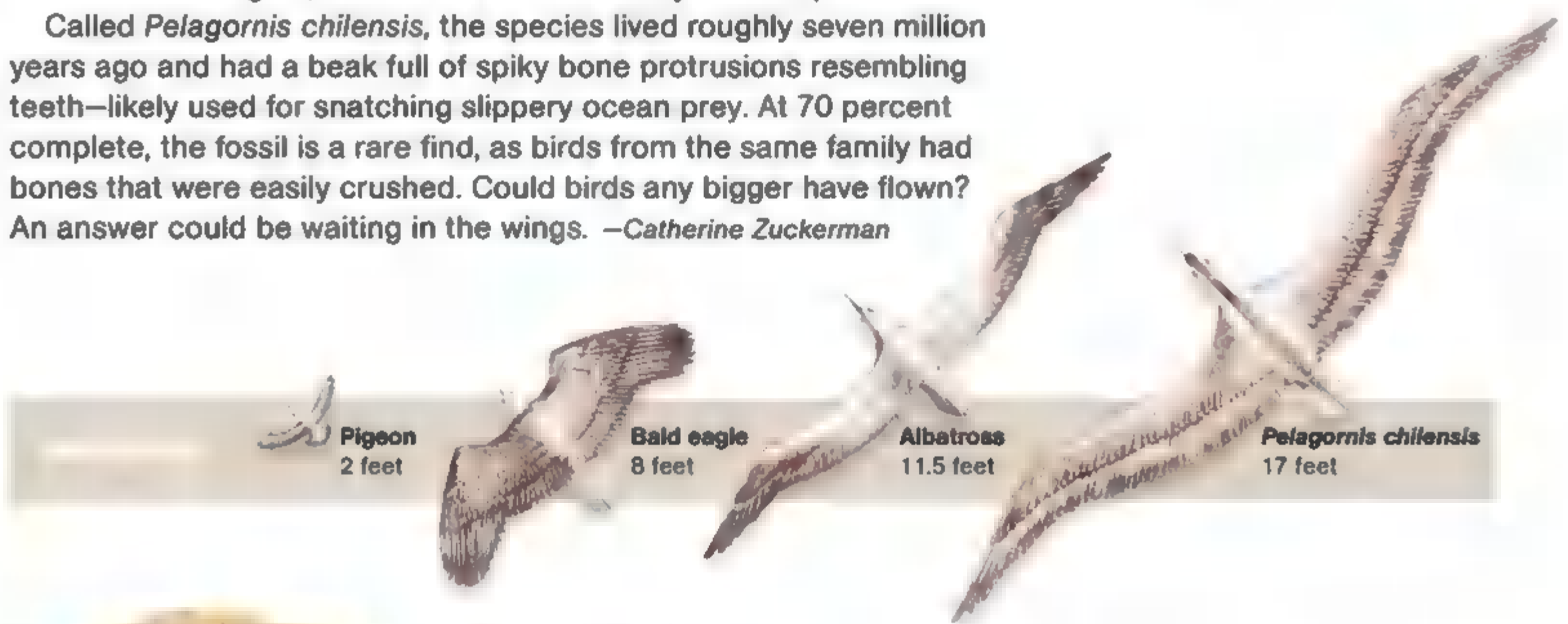
OPENS IN THEATERS MARCH 18



Easy Glider While hunting for shark teeth in Chile a few years ago, fossil collectors hit a giant jackpot: the nearly intact remains of a prehistoric seabird whose wingspan stretched almost 17 feet. “It’s one of the largest ever recorded for a living or extinct bird,” says David Rubilar-Rogers, co-author of a 2010 study on the specimen.

Called *Pelagornis chilensis*, the species lived roughly seven million years ago and had a beak full of spiky bone protrusions resembling teeth—likely used for snatching slippery ocean prey. At 70 percent complete, the fossil is a rare find, as birds from the same family had bones that were easily crushed. Could birds any bigger have flown? An answer could be waiting in the wings. —Catherine Zuckerman

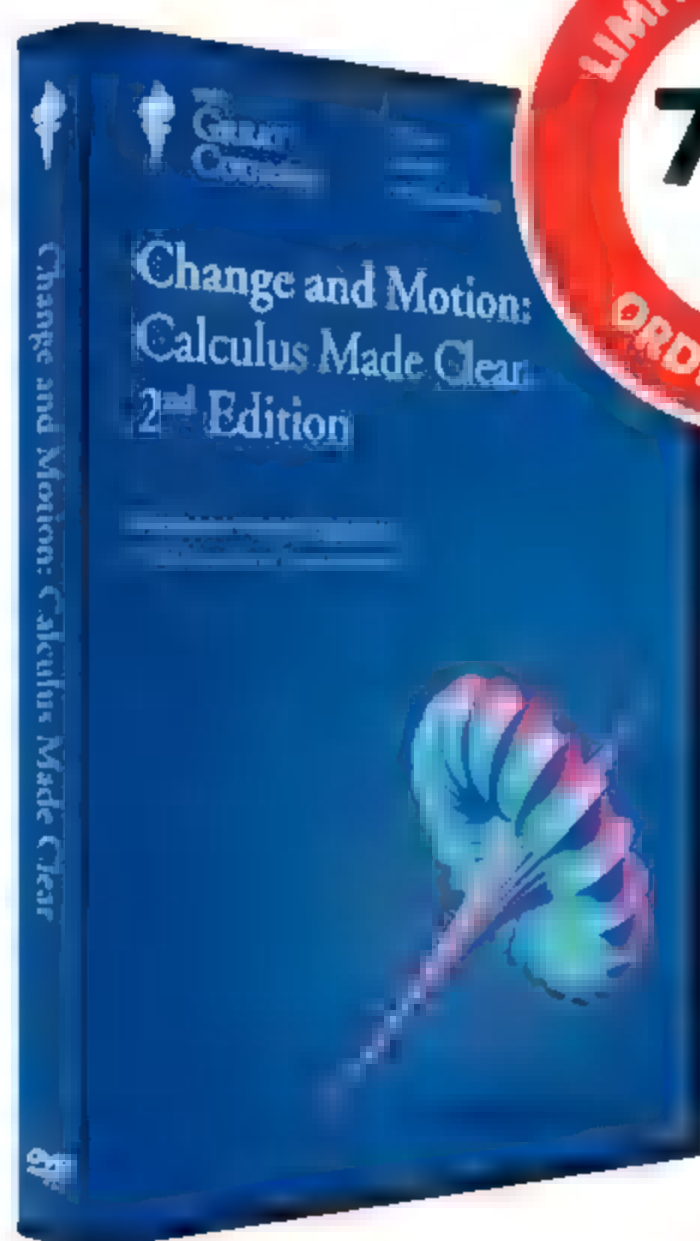
This skeleton of a prehistoric seabird is helping scientists study the anatomy of flight in supersize birds.



Ancient Bloom A tiny two-inch fossil (left) found in southern Argentina could offer clues to how sunflowers and daisies came to be so ubiquitous. At 47.5 million years old, it’s the oldest evidence of the huge Asteraceae family—which also includes thistles and artichokes—and backs the theory that the group first took root in South America. Now botanists are using the find to figure out how these plants managed to disperse onto every continent except Antarctica. —CZ



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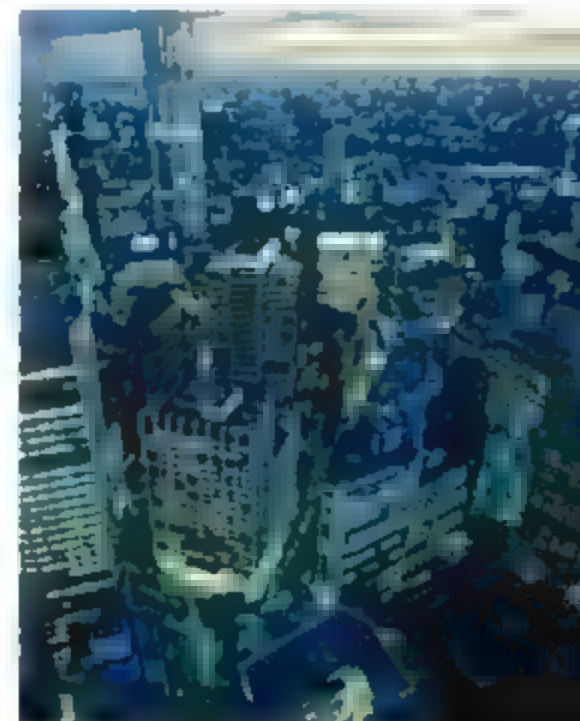
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*Annual grains feed the world,
but they create perennial problems.
Some think we need a*

Perennial Solution

HUMANS MADE AN UNWITTING but fateful choice 10,000 years ago as we started cultivating wild plants: We chose annuals. All the grains that feed billions of people today—wheat, rice, corn, and so on—come from annual plants, which sprout from seeds, produce new seeds, and die every year. “The whole world is mostly perennials,” says USDA geneticist Edward Buckler, who studies corn at Cornell University. “So why did we domesticate

annuals?” Not because annuals were better, he says, but because Neolithic farmers rapidly made them better—enlarging their seeds, for instance, by replanting the ones from thriving plants, year after year. Perennials didn’t benefit from that kind of selective breeding, because they don’t need to be replanted. Their natural advantage became a handicap. They became the road not taken.

Today an enthusiastic band of scientists has

The roots of a young winter wheat plant are dwarfed by those of its perennial cousin, wheatgrass, which remain long and full year-round.

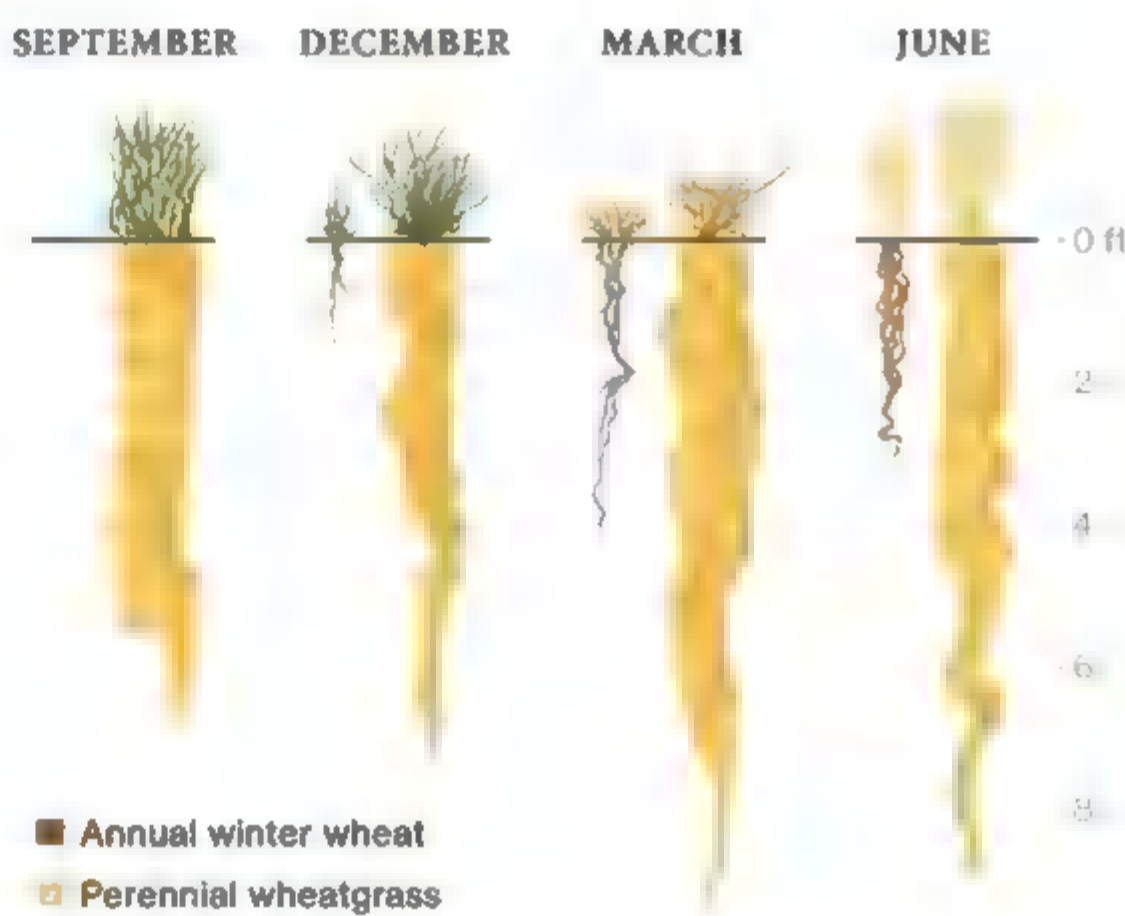
Roots continue ---->

Perennial wheatgrass



gone back to that fork in the road: They're trying to breed perennial wheat, rice, and other grains. Wes Jackson, co-founder and president of the Land Institute in Salina, Kansas, has promoted the idea for decades. It has never had much money behind it. But plant breeders in Salina and elsewhere are now crossing modern grains with wild perennial relatives; they're also trying to domesticate the wild plants directly. Either way the goal is crops that would tap the main advantage of perennials—the deep, dense root systems that fuel the plants' rebirth each spring and that make them so resilient and resource efficient—without sacrificing too much of the grain yield that millennia of selection have bred into annuals.

We pay a steep price for our reliance on high yields and shallow roots, says soil scientist—and National Geographic emerging explorer—Jerry Glover of the Land Institute. Because annual root crops mostly tap into only the top foot or so of



soil, that layer gets depleted, forcing farmers to rely on large amounts of fertilizers to maintain high yields. Often less than half the fertilizer in the Midwest gets taken up by crops; much of it washes into the Gulf of Mexico, where it fertilizes algae blooms that cause a vast dead zone around the mouth of the Mississippi. Annuals also promote heavy use of pesticides or (Continued)



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THE BIG IDEA

Perennials are thrifty. *Their long roots hold on to soil, water, and fertilizer, which means less pollution.*

tillage because they leave the ground bare much of the year. That allows weeds to invade.

Above all, leaving the ground bare after harvest and plowing it in planting season erodes the soil. No-till farming and other conservation practices have reduced the rate of soil loss in the U.S. by more than 40 percent since the 1980s, but it's still around 1.7 billion tons a year. Worldwide, one estimate put the rate of soil erosion from plowed fields at ten to a hundred times the rate of soil production. "Unless this disease is checked, the human race will wilt like any other crop," Jackson wrote 30 years ago. As growing populations force farmers in poor countries onto steeper, erodible slopes, the "disease" threatens to get worse.

Perennial grains would help with all these problems. They would keep the ground covered, reducing erosion and the need for pesticides, and their deep roots would stabilize the soil and make the grains more suitable for marginal lands.

"Perennials capture water and nutrients 10 or 12 feet down in the soil, 11 months of the year," Glover says. The deep roots and ground cover would also hold on to fertilizer—reducing the cost to the farmer as well as to the environment.

The perennial wheat-wheatgrass hybrid now growing at the Land Institute can already be made into flour. Yields are too low to compete with annual wheat in Kansas—but maybe not in Nepal, which has steeper slopes and a harsher climate, and where a researcher is now testing perennial hybrids in small plots. Amber waves of perennial grain may be decades away, but the emergence of cheap DNA sequencing is allowing plant breeders to work much faster than they used to. Buckler thinks that for a tiny fraction of the billions spent annually on corn research, one could create field-testable perennial corn in as little as ten years. "I think we should take a shot at revolutionizing agriculture," he says. —Robert Kunzig





terrace
royal retreat
to the Incas
precision-cut stones
placed cascades of terraces

Lofty Ambitions of the Inca

Rising from obscurity to the heights of power, a succession of Andean rulers subdued kingdoms, sculpted mountains, and forged a mighty empire.



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IN 1999 THE LOCAL GOVT. APPROVED THE USE OF
ROCKS TO BUILD A FIRE PIT IN THE MOUNTAIN
TO USE THE LOCAL WOODS AS FUEL. THE
CHALLENGE WAS TO FIND A WAY TO
CONSTRUCT THE FIRE PIT USING ONLY
THE LOCAL WOODS AS FUEL.





Five centuries ago, these mummies were bound into bundles, which resulted in contorted poses but made them easier to carry. Modern looters tore off their wrappings, hoping to find gold.



BY HEATHER PRINGLE

PHOTOGRAPHS BY ROBERT CLARK



On the remote Peruvian island of Taquile, in the middle of the great Lake Titicaca, hundreds of people stand in silence on the plaza as a local Roman Catholic priest recites a prayer. Descended in part from Inca colonists sent here more than 500 years ago, the inhabitants of Taquile keep the old ways. They weave brilliantly colored cloth, speak the traditional language of the Inca, and tend their fields as they have for centuries. On festival days they gather in the plaza to dance to the sound of wooden pipes and drums.



Still standing after five and a half centuries of earthquakes, this stone wall in Ollantaytambo was once part of an estate owned by ruler Pachacutec Inca Yupanqui. The Inca had no iron tools or wheeled vehicles, yet they managed to quarry and move stones that weighed more than a hundred tons.

Today, on a fine summer afternoon, I watch from the sidelines as they celebrate the fiesta of Santiago, or St. James. In Inca times this would have been the festival of Illapa, the Inca god of lightning. As the prayers draw to a close, four men dressed in black raise a rustic wooden litter holding a painted statue of Santiago. Walking behind the priest in a small procession, the bearers carry the saint for all in the plaza to see, just as the Inca once shouldered the mummies of their revered kings.

The names of those Inca rulers still resonate with power and ambition centuries after their demise: Viracocha Inca (meaning Creator God Ruler), Huascar Inca (Golden Chain Ruler), and Pachacutec Inca Yupanqui (He Who Remakes the World). And remake the world they did. Rising from obscurity in Peru's Cusco Valley during the 13th century, a royal Inca dynasty charmed, bribed, intimidated, or conquered its rivals to create the largest pre-Columbian empire in the New World.

Scholars long possessed few clues about the lives of Inca kings, apart from flattering histories that Inca nobles told soon after the arrival of Spanish conquistadores. The Inca had no system of hieroglyphic writing, as the Maya did, and any portraits that Inca artists may have made of their rulers were lost. The royal palaces of Cusco, the Inca capital, fell swiftly to the European conquerors, and a new Spanish colonial city rose on their ruins, burying or obliterating the Inca past. In more recent times, civil unrest broke out in the Peruvian Andes in the early 1980s, and few archaeologists ventured into the Inca heartland for more than a decade.

Now archaeologists are making up for lost time. Combing rugged mountain slopes near Cusco, they are discovering thousands of previously unknown sites, shedding new light on the origins of the Inca dynasty. Gleaning clues from colonial documents, they are relocating the lost estates of Inca rulers and examining the complex

Vancouver-based author Heather Pringle specializes in archaeological subjects. Photographer Robert Clark is a regular contributor to the Geographic.

upstairs-and-downstairs lives of imperial households. And on the frontiers of the lost empire, they are piecing together dramatic evidence of the wars Inca kings fought and the psychological battles they waged to forge dozens of fractious ethnic groups into a united realm. Their extraordinary ability to triumph on the battlefield and to build a civilization, brick by brick, sent a clear message, says Dennis Ogburn, an archaeologist at the University of North Carolina at Charlotte: "I think they were saying, We are the most powerful people in the world, so don't even think of messing with us."

ON A SUN-WASHED July afternoon, Brian Bauer, an archaeologist from the University of Illinois at Chicago, stands in the plaza of the sprawling Inca ceremonial site of Maukallacta, south of Cusco. He takes a swig of water, then points to a towering outcrop of gray rock just to the east.

Carved into its craggy summit are massive steps, part of a major Inca shrine. Some 500 years ago, says Bauer, pilgrims journeyed here to worship at the steep outcrop, once regarded as one of the most sacred places in the empire: the birthplace of the Inca dynasty.

Bauer, a wiry 54-year-old in a battered ball cap and blue jeans, first came to Maukallacta in the early 1980s to uncover the origins of the Inca Empire. At the time most historians and archaeologists believed that a brilliant, young Andean Alexander the Great named Pachacutec became the first Inca king in the early 1400s, transforming a small collection of mud huts into a mighty empire in just one generation. Bauer didn't buy it. He believed the Inca dynasty had far deeper roots, and Maukallacta seemed the logical place to look for them. To his bewilderment, two field seasons of digging turned up no trace of primeval Inca lords.



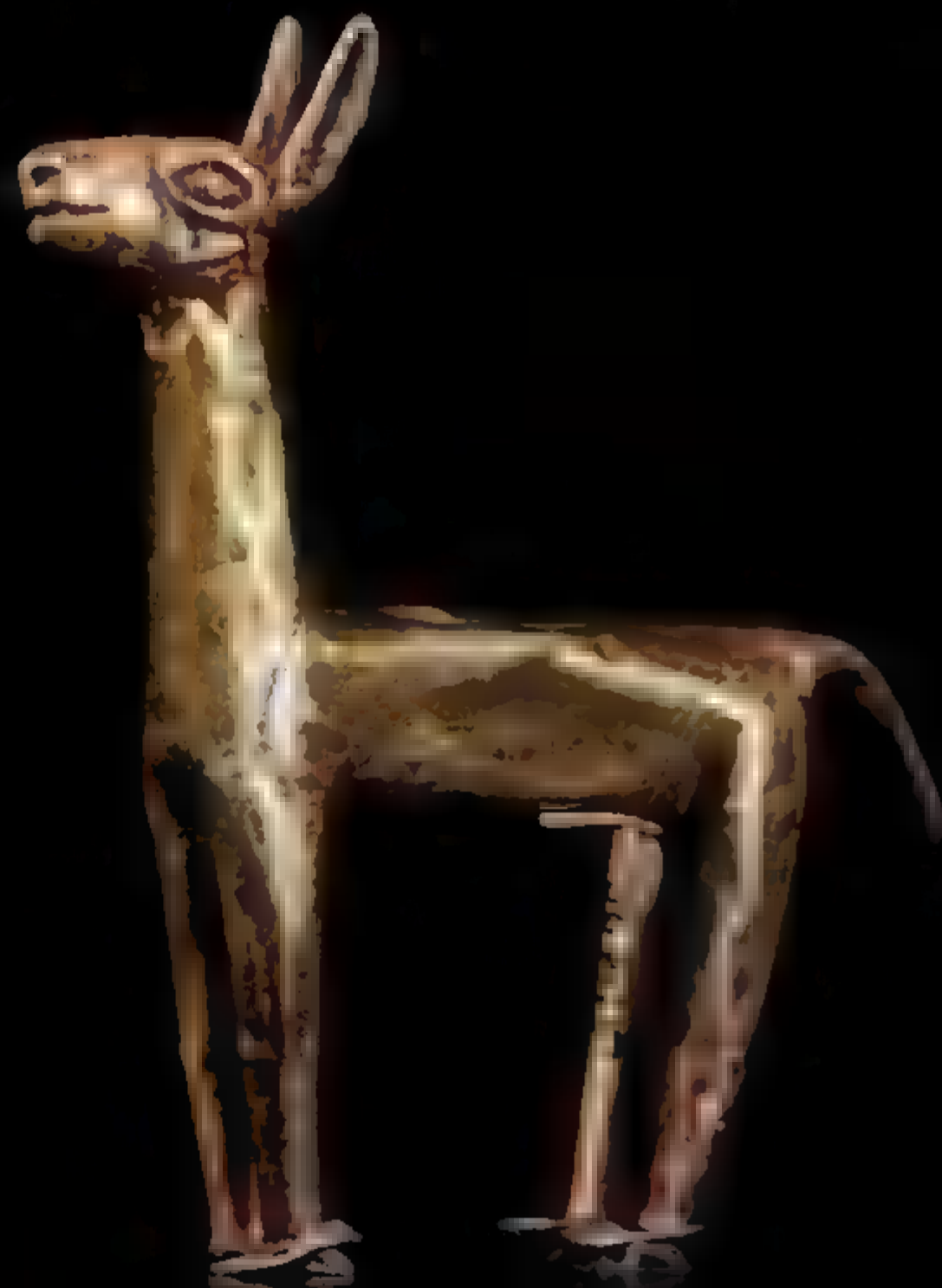
AT MUSEO NACIONAL DE ARQUEOLOGÍA, ANTHROPOLOGÍA E HISTORIA, LIMA, PERU; AT MUSEO SANTUARIOS DE ALTURA, AREQUIPA, PERU (NOBLE)

So Bauer shifted north, to the Cusco Valley. With colleague R. Alan Covey, now an archaeologist at Southern Methodist University (SMU) in Dallas, and a team of Peruvian assistants, he marched up and down the steep mountain slopes in straight transect lines for four field seasons, recording every scattering of pottery sherds or toppled stone wall he came across. Persistence paid off. Bauer and his colleagues eventually discovered thousands of previously unknown Inca sites, and the new evidence revealed for the first time how an Inca state had risen much earlier than previously believed—sometime between 1200 and 1300. The ancient rulers of the region, the mighty Wari (Huari) lords who reigned from a capital near modern Ayacucho, had fallen by 1100, in part due to a severe drought that afflicted the Andes for a century or more. In the ensuing turmoil, local chiefs across the Peruvian highlands battled over scarce water and led

raiders into neighboring villages in search of food. Hordes of refugees fled to frigid, wind-swept hideouts above 13,000 feet.

But in the fertile, well-watered valley around Cusco, Inca farmers stood their ground. Instead of splintering apart and warring among themselves, Inca villages united into a small state capable of mounting an organized defense. And between 1150 and 1300, the Inca around Cusco began to capitalize on a major warming trend in the Andes.

As temperatures climbed, Inca farmers moved up the slopes by 800 to 1,000 feet, building tiers of agricultural terraces, irrigating their fields, and reaping record corn harvests. “These surpluses,” says Alex Chepstow-Lusty, a paleoecologist at the French Institute for Andean Studies in Lima who has been studying the region’s ancient climate, allowed the Inca to “free up many people for other roles, whether building roads or maintaining



The Spanish melted down almost every Inca artifact of silver or gold. Rare pieces that survive include a ritual cup adorned with a sacred feline and figurines from sacrificial burials: a man with the stretched earlobes of a noble, a woman with a wad of coca in her left cheek, and a llama.



KINGS FOR LIFE—AND BEYOND

The mummies of former rulers sit in the main plaza of Cusco for a symbolic toast of *chicha*, or corn beer, as the current ruler offers a toast from a ritual platform. In his role as host, the ruler served as an intermediary between the present and the past—represented by his deceased ancestors. Each royal mummy was dressed in his finery and carried here from his estate, which he continued to own even after death. This ceremony, held every August before planting season, drew people from the four corners of the empire.

ART: JON FOSTER, JEFF OSBORN; AMANDA HOBBS, NGM STAFF. SOURCES: BRIAN S. BAUER, UNIVERSITY OF ILLINOIS AT CHICAGO; R. ALAN COVEY, SOUTHERN METHODIST UNIVERSITY; CAROLYN DEAN, UNIVERSITY OF CALIFORNIA, SANTA CRUZ; JEAN-PIERRE PROTZEN, UNIVERSITY OF CALIFORNIA, BERKELEY



The great plaza of Cusco was the political center of the Inca Empire. The Saphy River divided it into two sacred spaces, with the northeast area used for ceremonies.





Ambition Unbound

After centuries as a growing local power, the Inca dreamed of a greater realm. They went on to conquer 300,000 square miles in a few generations.

1 ca 1400
Having subdued their neighbors, Inca kings launch their first conquests beyond the Cusco region.

2 ca 1470
Pushing to the coast, the Inca defeat the Chimú Empire and carry off many Chimú artisans.

3 ca 1500
Turning south, the Inca capture a vast territory, extending their reach to the edge of Patagonia.

4 by 1532
In a final thrust along the eastern slope of the Andes, the Inca expand farther into the Amazon Basin.

THE INCA EMPIRE

Employing a shrewd combination of diplomacy, intermarriage, and military coercion, the Inca conquered a vast realm extending 2,500 miles along the mountainous spine of South America. At their height, they ruled as many as 12 million people, who spoke at least 20 languages. This fractious conglomeration quickly fell apart after the Spanish conquest in 1532.

Scale varies. This is a perspective. Distance from Lima to La Paz is 670 mi (1,078 km).

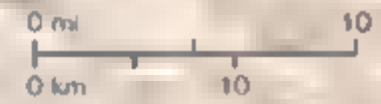
Present-day place names and boundaries shown.

IML/TAKES; MONREY; SON/DUMER; JAMES; SCARF; RITTER; NGIS STAFF; LANDSAT; INSET: GLOBAL LAND COVER FACILITY

SOURCES: BRIAN S. BAUER, UNIVERSITY OF ILLINOIS AT CHICAGO; P. ALAN COVEY, SOUTHERN METHODIST UNIVERSITY; TERENCE M. D'ALTROY, COLUMBIA UNIVERSITY

The Imperial Heartland

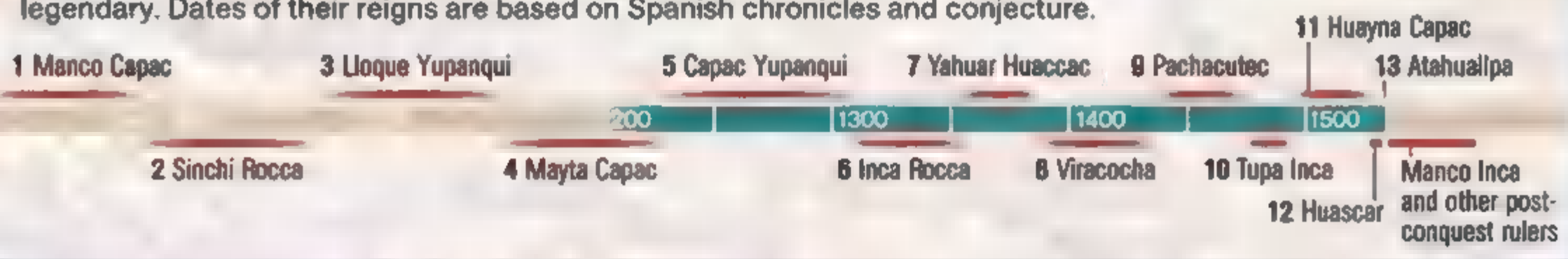
Archaeologists have discovered royal estates around Cusco, the Inca capital. Spanish records indicate the locations of royal mummies, but the mummies have since been lost.



- # Royal estate
- ✱ Mummy site
- Both
- Inca ruler (below)



Inca Rulers Inca oral histories told of a long succession of kings, some perhaps legendary. Dates of their reigns are based on Spanish chronicles and conjecture.



The Last Great Inca

Among the many native civilizations of the New World, the Inca developed a highly organized society that built the largest empire, unifying their territory with an extensive road network.



*Pre-Columbian cultural area that includes parts of present-day Mexico and Central America.



a large army.” In time Inca rulers could call up more conscripts and supply a larger army than any neighboring chief.

With this big stick, Inca kings began eyeing the lands and resources of others. They struck marriage alliances with neighboring lords, taking their daughters as wives, and dispensed generous gifts to new allies. When a rival lord spurned their advances or stirred up trouble, they flexed their military might. In all the surrounding valleys, local lords succumbed one by one, until there was only one mighty state and one capital, the sacred city of Cusco.

Flush with success, Inca kings set their sights farther afield, on the wealthy lands surrounding Lake Titicaca. Sometime after 1400, one of the greatest Inca rulers, Pachacutec Inca Yupanqui, began planning his conquest of the south. It was the dawn of empire.

MASSED ON A HIGH, cold Peruvian plain north of the great lake in the mid-1400s, the army of the Colla bristled with battle gear, daring the Inca invaders to make war. Pachacutec scanned the enemy ranks in silence, preparing for the great battle ahead. The lords of the Titicaca region



A patchwork of farms covers land near Chinchero that likely belonged to the royal estate of Tupa Inca Yupanqui. The Inca expertly worked every agricultural niche in their vast territory. At this elevation, more than 12,000 feet, they grew tubers such as potatoes and herded domesticated llamas and alpacas.

were haughty men, ruling as many as 400,000 people in kingdoms arrayed around the lake. Their lands were rich and desirable. Gold and silver veined the mountains, and herds of alpacas and llamas fattened in lush meadows. Military success in the Andes depended on such livestock. A llama, the only draft animal on the continent, could carry 70 pounds of gear on its back. Llamas, along with alpacas, also provided meat, leather, and fiber for clothing. They were jeeps, K rations, and fatigues all rolled into one—crucial military assets. If the Inca king could not conquer the Titicaca lords who owned these vast herds, he would live in fear of the day these lords would come to conquer him.

Seated on a shimmering litter, Pachacutec issued the order to attack. Playing panpipes carved from the bones of enemies and war drums fashioned from the flayed skins of dead foes, his soldiers advanced toward the Colla forces, a moving wall of terror and intimidation. Then both sides charged. When the fog of battle lifted, Colla bodies littered the landscape.

In the years that followed, Pachacutec and his descendants subdued all the southern lords. “The conquest of the Titicaca Basin was the jewel in the crown of the Inca Empire,” says Charles Stanish, an archaeologist at the University of California, Los Angeles. But military victory was only the first step in the Inca’s grand strategy of empire building. Officials next set about establishing civil control.

If provinces mounted resistance, Inca sovereigns reshuffled their populations, deporting restive inhabitants to the Inca heartland and replacing them with loyal subjects. Residents of remote walled villages were moved to new Inca-controlled towns sited along Inca roads—roads that sped the movement of Inca troops. Inca governors ordered the construction of roadside storehouses for those troops and commanded local communities to fill them with provisions. “The Inca were the organizational geniuses of the Americas,” says Stanish.

Under Inca rule, Andean civilization flowered as never before. Inca engineers transformed fragmentary road networks into interconnected





Women waiting for a lift at El Mirador in Málaga wear clothing that reflects their country's history. Their shawls follow an Inca tradition, but their upturned hats and full skirts were inspired by the Spanish



highways. Inca farmers mastered high-altitude agriculture, cultivating some 70 different native crops and often stockpiling three to seven years' worth of food in vast storage complexes. Imperial officials excelled at the art of inventory control, tracking storehouse contents across the realm with an ancient Andean form of computer code—colored and knotted cords known as quipus. And Inca masons raised timeless architectural masterpieces like Machu Picchu, which continues to awe visitors today. (See “Finding Machu Picchu,” page 59.)

By the time the Inca king Huayna Capac took

power around 1493, little seemed beyond the reach of the Inca dynasty. To bring grandeur to his new capital in Ecuador, Huayna Capac put more than 4,500 rebellious subjects to work hauling immense stone blocks all the way from Cusco—a distance of nearly a thousand miles up and down vertiginous mountain roads. And in the Inca heartland, a small army of men and women toiled to construct a royal estate for Huayna Capac and his family. At the king's bidding, they moved the Urubamba River to the southern side of the valley. They leveled hills and drained marshes, then planted corn and other



Under the care of a watchman, corn dries in the autumn air of Yucay. The Inca developed high-yield varieties of this grain that continue to thrive in the rich soil of the Urubamba River Valley. The empire's main crop, corn filled state granaries, fed laborers and soldiers, and was fermented into beer for festivals.

crops such as cotton, peanuts, and hot peppers from far corners of the empire. In the center of the estate, they laid stones and bricks for Huayna Capac's new country palace, Quispiguanca.

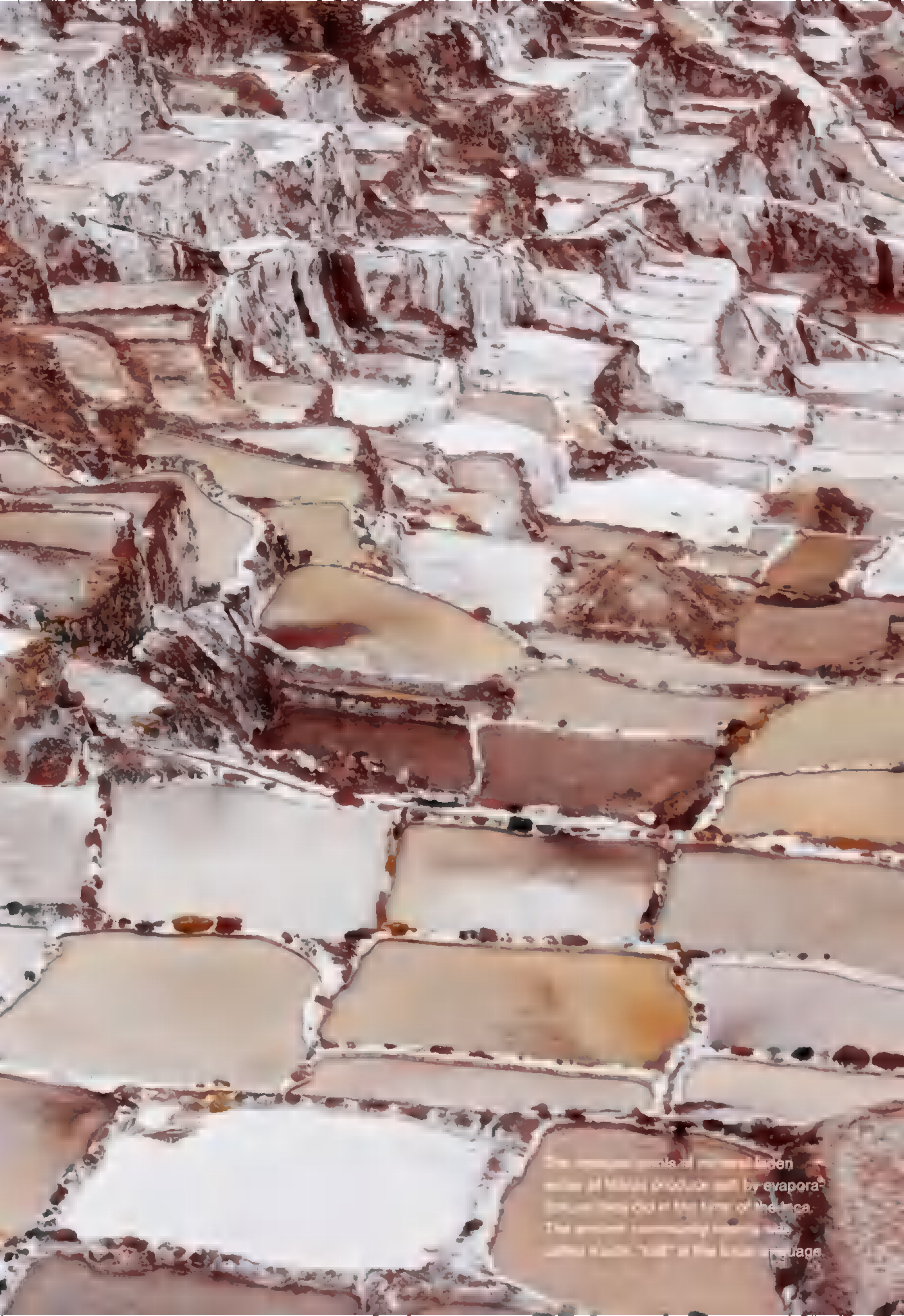
As the late afternoon sun slants down, I wander the ruins of Quispiguanca with Alan Covey, the archaeologist from SMU. Situated on the outskirts of the modern town of Urubamba, Quispiguanca basks in one of the warmest and sunniest microclimates in the region, which provided the Inca royal family a welcome escape from the cold of Cusco. The estate's gatehouses now look out on a field of pungent cilantro, and its surviving walls enclose a royal compound that once sprawled over an area equivalent to some seven soccer fields.

Encircled by parkland, fields, and gardens, Quispiguanca was an Inca version of Camp David, a retreat from the world, a place for a warrior-king to unwind after military campaigning. Here Huayna Capac entertained guests in the great halls and gambled with courtiers and other favorites, while his queen gardened and tended doves. The grounds boasted a secluded lodge and a forest reserved for hunting deer and other game. In the fields hundreds of workers cleared irrigation channels, raised and mended terrace walls, and sowed corn and a host of exotic crops. These provided Huayna Capac with bountiful harvests and enough corn beer to entertain his subjects royally during Cusco's annual festivals.

Quispiguanca was not the only spectacular estate. Inca kings inherited little more than their titles, so each new sovereign built a city palace and country home for himself and his lineage shortly after assuming power. To date archaeologists and historians have located ruins of roughly a dozen royal estates built by at least six Inca kings.

Even after these kings died, they remained the powers behind the throne. "The ancestors were a key element of Andean life," says Sonia Guillén, director of Peru's Museo Leymebamba. When Huayna Capac perished of a mysterious disease in Ecuador around 1527, retainers mummified his body and carried it back to Cusco. Members of the royal family frequently visited the deceased monarch,





The terraces are made of natural stone
and are used for growing crops. The
terraces are built on the slope of the Inca.
The terraces are used for growing
crops like corn, potatoes, and
beans.

asking his advice on vital matters and heeding the replies given by an oracle sitting at his side. Years after his death, Huayna Capac remained the owner of Quispiguanca and the surrounding estate. Indeed, royal tradition dictated that its harvest keep his mummy, servants, wives, and descendants in style for eternity.

IT WAS DURING the rainy season in 1533, an auspicious time for a coronation, and thousands of people were packed into the main plaza of Cusco to celebrate the arrival of their new teenage king. Two years earlier, amid a civil war, foreign invaders had landed in the north. Metal-clad and bearing lethal new weapons, the Spaniards had journeyed to the northern Inca town of Cajamarca, where they took prisoner the Inca king, Atahualpa. Eight months later, they executed their royal captive, and in 1533 their leader, Francisco Pizarro, picked a young prince, Manco Inca Yupanqui, to rule as a puppet king.

In the far distance, voices of the young king's bearers echoed through the streets, singing songs of praise. Falling silent, celebrants watched the royal teenager enter the square, accompanied by the mummies of his ancestors, each richly attired and seated on a splendid litter. The wizened kings and their consorts reminded all that Manco Inca descended from a long line of kings. Rulers of other realms might content themselves with displaying carved or painted images of their glorious ancestors. The Inca kings went one better, displaying the expertly preserved bodies of their forefathers.

In the months that followed, the Spanish invaders seized the palaces of Cusco and the spacious country estates and took royal women as mistresses and wives. Incensed, Manco Inca rebelled and in 1536 tried to drive them from the realm. When his army suffered defeat, he fled Cusco for the jungle city of Vilcabamba, from which he launched guerrilla attacks. The Spanish wouldn't subdue the stronghold until 1572.

In the turmoil of those decades, the Inca's sprawling network of roads, storehouses, temples, and estates began slowly falling into ruin. As the empire crumbled, the Inca and their

descendants made a valiant attempt to preserve the symbols of imperial authority. Servants collected the precious bodies of the sacred kings and concealed them around Cusco, where they were worshipped in secret—and in defiance of Spanish priests. In 1559 Cusco's chief magistrate, Juan Polo de Ondegardo, resolved to stamp out this idolatry. He launched an official search for the bodies, questioning hundreds. With this information he tracked down and seized the remains of 11 Inca kings and several queens.

For a time colonial officials in Lima displayed the mummies of Pachacutec, Huayna Capac, and two other royals as curiosities in the Hospital of San Andrés in Lima, a facility that admitted only European patients. But the damp coastal climate wreaked havoc with the bodies. So Spanish officials buried the greatest of the Inca kings in secrecy in Lima, far from the Andes and the people who loved and worshipped them.

In 2001 Brian Bauer and two Peruvian colleagues, historian Teodoro Hampe Martínez and archaeologist Antonio Coello Rodríguez, went looking for the mummies of the Inca kings, hoping to right a historic wrong and restore to Peruvians an important part of their cultural heritage. "Can you imagine," Bauer asks, "how American citizens would feel if the British had taken the bodies of the first several presidents back to London during the War of 1812?"

For months Bauer and his colleagues pored over old architectural plans of the Hospital of San Andrés, now a girls' school in central Lima. Eventually they identified several possibilities for the burial site of Pachacutec and Huayna Capac. Using ground-penetrating radar, they scanned the likeliest areas, turning up what appeared to be a vaulted underground crypt. Bauer and his Peruvian teammates were thrilled.

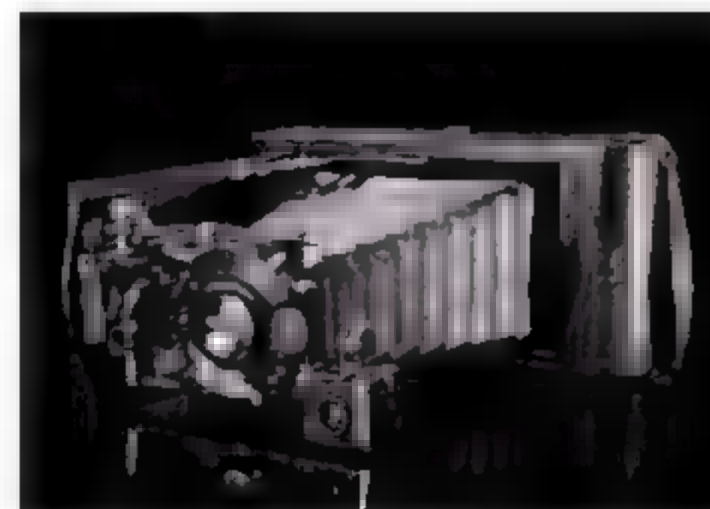
When the archaeologists finally dug down and opened the door of the dusty chamber, they were crestfallen. The crypt lay empty. Quite possibly, says Bauer, workmen removed the contents while renovating the hospital after a severe earthquake. Today no one can say where Peru's greatest kings lie. Concludes Bauer sadly, "The fate of the royal Inca mummies remains unknown." □



FINDING MACHU PICCHU

ON HANDS AND KNEES, THREE MEN CRAWLED up a slick and steep mountain slope in Peru. It was the morning of July 24, 1911. Hiram Bingham III, a 35-year-old assistant professor of Latin American history at Yale University, had set out from his expedition camp on the Urubamba River with two Peruvian companions to investigate reported ruins on a towering ridge known as Machu Picchu ("old mountain" in the Inca language). Nearly 2,000 feet above the valley floor, the climbers met two farmers who had moved up the mountain to avoid tax collectors. The men assured an increasingly skeptical Bingham that the rumored ruins lay close at hand and sent a young boy along to lead the way. When Bingham finally reached the site, he gaped in astonishment at the scene before him. Rising out of the thick tangle of

From his camp at Machu Picchu, Hiram Bingham set out to study one of the few Inca sites untouched by the Spanish invaders. Using a sturdy Kodak camera, he took thousands of photos to document his work.





undergrowth was a maze of terraces and walls, an Inca ghost town hidden from the outside world for nearly 400 years. "It seemed like an unbelievable dream," he later wrote. "What could this place be?"

Bingham later acknowledged that he was not the first to discover Machu Picchu—a Peruvian tenant farmer had inscribed his name on one of its walls nearly a decade earlier—but he was the first to study the site scientifically. With financial support from Yale University and the National Geographic Society, Bingham's crews cleared the vegetation that had reclaimed the peak, mapped and photographed the ruins, and shipped thousands of artifacts to Yale's Peabody Museum of Natural History.

As news of the "lost city" spread, scholars tried to puzzle out just what kind of place Machu Picchu was. A fortress? A ceremonial site? For many decades no one really knew. A breakthrough came in the 1980s when historians found a dusty legal document from 1568, less than 40 years after the Spanish conquest of Peru.

Descendants of the ruler Pachacutec Inca Yupanqui, in a petition to the Spanish court, stated that their royal ancestor had owned lands at a place called Picchu, very close to where Machu Picchu sits today. Subsequent studies of the site's architecture and artifacts—from simple pots used by servants to bronze mirrors fit for a queen—suggest that Pachacutec lived in comfort at this mountaintop retreat, dining from silver plates, washing in a private stone bath, and relaxing in an orchid-scented pleasure garden.

In recent years the fate of the artifacts Bingham collected during his three expeditions became the source of a bitter dispute between the Peruvian government and Yale University. Last fall, as the hundredth anniversary of Bingham's discovery drew near, Yale yielded and announced that it would return all the artifacts to Peru.

Today this icon of the Inca world continues to beckon explorers and pilgrims. Each day nearly 2,000 people pour through the entrance and behold the sight that caused Bingham to exclaim, "It fairly took my breath away." —Heather Pringle



Crowning a ridge above the Urubamba River, the royal estate emerges after months of work to clear centuries of overgrowth. The almost impenetrable terrain had preserved the site in isolation. Bingham's team uncovered a wealth of artifacts in the ruins, including a crescent pendant with curling waves, a knife blade bearing a fisherman and his catch, and a shawl pin adorned with birds.





A JEWEL IN TWO CROWNS

Russia's paradise lost belongs to UKRAINE — and that's

Chords of friendship bind accordionist
Olesya Kamovich and comrades, who
meet Sundays in Sevastopol to sing.

where the trouble begins.





BEACH, BUND, SEA

are the playgrounds for six million tourists a year, many from Russia and Ukraine, who come to beaches like this one at Crimea's Sudak. Black Sea resorts were favored by communist bigwigs in the Soviet era.

BY CATHY NEWMAN
PHOTOGRAPHS BY GERD LUDWIG

THE PAST *is never past in Sevastopol.*

It waves from flagpoles and drapes the parade stand on patriotic holidays. It finds sanctuary in war monuments and is posted on signs: Lenin Square, Heroes of Stalingrad Street, Cinema Moscow. It even simmers in a pot of borscht.

Take Galina Onischenko's version of the eastern European staple. "This is Russian borscht," she said, setting down a porcelain bowl of "green" or summer borscht with its dill-flecked mosaic of beets, carrots, and potatoes. "No lard with garlic like they put in Ukrainian borscht."

Galina, a 70-year-old grandmother with a cumulous cloud of white hair and stern, cornflower blue eyes, had returned to her fifth-floor walk-up from marching down Lenin Street waving a Soviet Navy flag in support of her beloved Black Sea Fleet. "Sevastopol is a Russian city, and we will never put up with the fact that Ukraine is in charge," she said.

Though Galina would protest, borscht, according to Russian food historian V. V. Pokhlebin, is originally Ukrainian. Though Galina protests, Sevastopol, a city in Crimea, is Ukrainian too.

THE CRIMEAN PENINSULA is a diamond suspended from the south coast of Ukraine by the thin chain of the Perekop Isthmus, embraced by the Black Sea, on the same latitude as the south of France. Warm, lovely, lush, with a voluptuously curved coast of sparkling cliffs, it was ■ jewel of the Russian Empire, the retreat of Romanov

tsars, and the playground of Politburo fat cats. Officially known as the Autonomous Republic of Crimea, it has its own parliament and capital, Simferopol, but takes its orders from Kiev.

Physically, politically, Crimea is Ukraine; mentally and emotionally, it identifies with Russia and provides, a journalist wrote, "a unique opportunity for Ukrainians to feel like strangers on their own territory." Crimea speaks to the persistence of memory—how the past lingers and subverts.

IN 1954 Nikita Sergeevich Khrushchev, First Secretary of the Communist Party of the Soviet Union, signed Crimea over to Ukraine as a gesture of goodwill. Galina was 14 at the time.

"Illegal," she said, when asked about the hand-over. "There was no referendum. No announcement. It just happened."

What was Khrushchev thinking?

"He wasn't," she snapped. "Khrushchev had roaches in his head."

Crimea was a lovely present, but the box was empty. Ukraine was part of the Soviet Union anyway. "My parents discussed the transfer, but we weren't concerned," Galina said. Moscow was still in charge. No one could have ever imagined the 1991 collapse of the Soviet Union, when Crimea would be pulled out of the orbit of Russian rule along with an independent Ukraine.

Do you miss the Soviet Union? I asked Galina, as she reminisced about the stability of life



TO REMEMBER THE SACRIFICE of fallen soldiers is viewed as a holy duty in Sevastopol, which endured a 247-day-long siege by Hitler's army in 1941-42. Yuri Perov, a Ukrainian naval cadet, takes the bus to his barracks after rehearsal for the Victory Day parade.

under the Soviets. Prices were artificially low. "You could get a kilo of sugar for 78 kopeks," she said. "Butter, only 60! Now, I don't even buy it." Education and medical care were free. As for a vacation: "I could go to a resort"—now completely out of the question on her monthly pension of \$130.

"Yes, we have a longing for the Soviet Union," she said. "But it cannot come back, no matter how much we wish. We can only *toskavat*."

Toskavat, verb, to long for. *Toska*, noun, a longing, darker than nostalgia, verging on depression. Russian culture is embedded in a matrix of *toska*. When in *Three Sisters*, by Anton Chekhov (who owned a dacha in Crimea), Irina wistfully says, "Oh, to go to Moscow, to Moscow!" that is *toska*. If Sevastopol, where 70 percent of the population is ethnic Russian, could talk, I imagine it too saying, To Moscow, to Moscow. In a 2009 poll by the Razumkov Centre, a top Ukrainian think tank, nearly a third of the Crimean respondents said they wanted their

region to secede from Ukraine and become part of Russia.

In some ways it still is. But not just Russia. Crimea is practically a throwback to the old Soviet Union: the Early Concrete Bunker style of architecture, the rusting hulks of Russian warships in the harbor, the hammer-and-sickle medallions on the iron gates of Primorsky Park. It's also attitude. Brusque, rigid, humorless: the worst kind of Soviet hangover. You can take Crimea out of the Soviet Union; to pry the Soviet Union out of Crimea is something else. When I asked Yelena Nikolayevna Bazhenova, director of a Sevastopol-based tour company, why Crimea with its lovely seaside didn't attract more tourists, she hesitated. "We are not accustomed to greeting people with a smile," she finally said.

Crimea also sounds Russian. Ukrainian may

Editor at Large Cathy Newman wrote about Venice in August 2009. Gerd Ludwig photographed "Moscow Never Sleeps" for the August 2008 issue.

THE PERSISTENCE of memory is on parade at the May 9 Victory Day celebrations in Sevastopol, when Russian and Ukrainian troops, citizens, and veterans of the Soviet Army honor those who helped defeat Nazi Germany.







CRIMEAN ROULETTE

Claimed by Russia in 1783, Crimea was made part of Ukraine in 1954. With the 1991 collapse of the Soviet Union, it remained in Ukraine, but the Russian Black Sea Fleet was allowed to stay in Sevastopol.

be the official language, but Russian is the lingua franca, even in city hall. Of 60 secondary schools in Sevastopol, only one holds classes completely in Ukrainian.

A quirk of history had swept Crimea away from Russia, leaving Moscow with its own share of toska. As a former Russian deputy foreign minister told Steven Pifer, a former U.S. ambassador to Ukraine: "In my head, I know Ukraine is an independent nation. In my heart, it is quite another thing." An inventory of Russian forfeiture in Crimea: the vineyards of Massandra and Inkerman; champagne the color of rubies; Yevpatoriya and Feodosiya, the briny health resorts of the west and east coasts; sun-bleached Yalta and Foros on the south coast; orchards heavy with peaches, cherries, and apricots; fields tawny with wheat.

Finally, harbors that never freeze. Unlike Russia, Crimea has the blessing of warmth. Sixty-five percent of Russia is covered in permafrost. None of Crimea is. A fifth of Russia is above the Arctic Circle. None of Crimea is. In February, when it is 14°F in Moscow, it can be 43 in Yalta. "Russia needs its paradise," Prince Grigory Potemkin, Catherine the Great's general

and lover, wrote in urging annexation. Nearly every European power had carved slices of Asia, Africa, and the Americas for their imperial platters; Russia was no different in its appetite to expand. In 1783 Catherine declared Crimea to be forever Russian, adding 18,000 square miles to the empire, extending its border to the Black Sea, paving the way for its rise as a naval power. Russia had claimed its paradise.

And kept it for 208 years, until the collapse of the Soviet Union. With the emergence of newly independent states, assets of the former empire—including its military bases—became the property of those states. But Catherine's prize was not readily relinquished. Russia had few cards to play, but one strong hand.

"We were seriously dependent on Russian gas and oil," explained a Ukrainian official. "Our debt to Russia was about a billion U.S. dollars. The pressure was terrible." The two nations brokered a deal in 1997. The fleet could stay until 2017. Ukraine was credited tens of millions of dollars against its debt. Last year the pro-Russian government led by newly elected President Viktor Yanukovich extended the lease for 25 years. Again, gas and oil were the lubricants.



PHOSPHORESCENT DUSK settles over Yalta, ■ fashionable resort for Russian nobility in the 19th century, war scorched in the 20th. Winston Churchill, participating in the 1945 conference that reconfigured postwar Europe, called the area the “Riviera of Hades.”

In exchange, Russia gave Ukraine, still drowning in debt, a 30 percent discount on natural gas.

Reaction was split, as usual, between the Russian-speaking east and south of Ukraine and the western regions, where Ukrainian nationalism runs strong.

Galina was pleased. The Russian Navy is in her genes. “My grandson is in the St. Petersburg military academy. My husband was a naval officer. My grandmother sewed sailor uniforms. I grew up in a house of heroes in a city of heroes.”

A city of heroes, a shrine to war. There are 2,300 memorials in Sevastopol; the city itself is practically bronzed. In 1945 it was awarded the Order of Lenin by the Soviet Union and named a Hero City for enduring a 247-day siege by Germany in World War II. Nearly a century earlier it suffered a 349-day siege by French, British, and Turkish troops in the Crimean War.

A cautionary note: Crimean history would suggest that it is folly to think that possession of any place, especially paradise, is anything other

than a tenancy. Crimea has passed from hand to hand, from Scythians to Greeks to Romans, Goths, Huns, Mongols, and Tatars. The latter, Turkic Muslims who migrated from the Eurasian steppes in the 13th century, were brutally targeted by Joseph Stalin and suffered mass deportation.

For three days in May 1944, Soviet militia pounded on Tatar doors, rounded up families, ordered them to pack, and expelled them to Central Asia—some 200,000 in all. Nearly half died from illness or starvation. “I was a young boy the night they came,” said Aydin Shemizade, a 76-year-old retired professor from Moscow. “I remember reaching for my book bag hanging on the wall. A soldier ripped it out of my hands.” His voice cracked. It was 20 years before he saw his homeland again.

In 1989 Mikhail Gorbachev allowed Tatars to return to Crimea. About 260,000 have done so, and they now represent 13 percent of Crimea’s population. Many live in squatters’ shacks on

*You can take
Crimea out of the
Soviet Union.
To pry the Soviet
Union out of Crimea
is something else.*

the outskirts of Simferopol and Bakhchysaray, hoping to reclaim their ancestral lands, haunted by dispossession and neglect. Even so, Tatars are largely pro-Ukrainian. They fear Russia reflexively—because of its nationalism and because it is the successor to the Soviet state—but Ukraine has no such baggage.

“Conversation about Crimea was constant in my family,” said Rustem Skibin, a 33-year-old Tatar artist with the hooded eyes and intensity of a falcon. We sat in his studio in back of his house in Acropolis, a village northeast of Simferopol, where the green of coastal Crimea gives way to the long horizon of the hot, dry steppes. “I heard the stories,” he said, “but I didn’t feel them.” The family had been forcibly resettled in Uzbekistan. “In 1991 we came back. Crimea was home. I went to Alushta to see the narrow streets with their small Tatar houses. I felt a sense of belonging and understood what it meant to be Tatar in my homeland.”

It is our motherland, I kept hearing, but whose motherland? For Galina Onischenko, the motherland was Russia. For Rustem Skibin, Crimea was the Tatar homeland and had been for at least seven centuries. For Sergey Kulik, 54, formerly an officer on a Russian submarine and now director of Nomos, a Sevastopol think tank, the motherland was Ukraine.

“I was sorry when the Soviet Union collapsed,” Kulik admitted over dinner one night. “Suddenly I was nowhere. I had to adjust.”

As a naval officer, Kulik had lived comfortably under Soviet rule, but the collapse inspired an epiphany. One could live a cushioned life and still be surrounded by repression, brutality, and falsehood. “I too have nostalgia, but it is not blind,” he explained.

When Ukraine became independent and took over Sevastopol (a closed city under the Soviets; entry required a permit), both governments faced the task of dividing up the Black Sea Fleet. Kulik and his fellow sailors—there were about 100,000—had a year to decide between the Russian and Ukrainian Navies.

“I didn’t think twice,” Kulik said. “I am Ukrainian. My parents are here. I speak Ukrainian. So I chose the Ukrainian Navy.” But what does it mean to be Ukrainian? I asked.

Kulik thought ■ while. “Being Ukrainian is like breathing,” he answered.

It seemed important to keep asking.

“In the 21st century it’s all about political boundaries. If you consider yourself to be Ukrainian, you are,” said Olexiy Haran, a political science professor.

“To be Ukrainian is the cherry trees in blossom, the ripening wheat, our stubborn people who work so hard, and the language I love,” insisted Anatoliy Zhernovoy, a lawyer and member of the Ukrainian Cossack movement. The Ukrainian Cossacks, whose forebears patrolled the steppes from the 13th to the 18th centuries, represent a muscular revival of national identity.

“The era of nationalism is past. To be Ukrainian is to be a citizen of Ukraine. That’s it,” said Vladimir Pavlovich Kazarin, the president’s representative to Crimea in Simferopol.

But Sergey Yurchenko of the Crimean Union of Cossacks disagrees. His paramilitary group of about 7,000 men consider themselves defenders of Russian nationalist ideology. I met Yurchenko at a Cossack compound an hour’s drive from Sevastopol, where in a month 200 boys 12 to 15 years old would attend summer camp and receive military-style training, which he’d supervise. Yurchenko wore ■ beret and battle fatigues and had the face of a pugilist who’d taken too many punches. He showed me the field where the boys would live in tents. “We teach them patriotism,” he said. They’d also be taught martial arts and how to shoot machine guns.

The camp was in the shadow of a 16-foot-high wood cross Cossacks had hauled up to the top of Ay-Petri Plateau. Government officials had



DEEP BREATHING IN A SALT ROOM is reputed to relieve asthma and skin conditions. Patients (above) at a state-owned sanatorium in Alushta are the beneficiaries of what's left of a Soviet system that ensured each citizen a paid vacation, subsidized spa treatments, and free health care. A younger crowd breaks loose at a foam party at a water park in Sudak (below).







THERE IS NO WINTER here, playwright Anton Chekhov wrote in his brother's letters from Crimea. This strip of Black Sea coastline east of Yalta, named Santa Barbara, is popular with families.



IN FALL, when shadows lengthen, grapes are harvested to be made into desert wines at the Massandra winery, built in the late 1800s near Yalta to house the cellars of Nicholas II, the last Russian tsar.





THE DRESS CODE IS CAMOUFLAGE for boys 12 to 15 years old (above), who attend a camp outside Sevastopol run by the Crimean Cossacks, a Russian nationalist group. Campers receive lessons in discipline and military training. The traditional Tatar wedding between Velila Menseitov and his bride, Sevilya, is a three-day celebration, complete with a henna party for the women.



demanded, unsuccessfully, that it be removed because it offended the local Tatar population. "You may have noticed, there are many Tatar squatters in the area. We keep an eye on them," Yurchenko said. "The Ukrainian government turns a blind eye. It's up to us to keep things in line." Keeping things in line included several fights in 2006 between Tatars and Cossacks at the Bakhchysaray market. "We don't wait for court orders to act," Yurchenko said of the violence that sent dozens to the hospital.

"He's a provocateur," Refat Chubarov, deputy of the Mejlis, the Tatar parliament, said at the mention of Yurchenko's name. "We're worried about any paramilitary movement, but the fact that kids are taught to play with guns is not nearly as important as the ideas they are taught to play with."

On one of those balmy summer days Slavs must dream about in winter, I sat in a restaurant in Balaklava with Konstantin Zatulin, a Russian Duma deputy. Zatulin, persona non grata in Ukraine during Viktor Yushchenko's tenure as president, was enjoying a warm welcome back under the new, pro-Russian regime. Our table overlooked the harbor where Russian submarines had once glided into port. Across the bay, beyond sleek white yachts at their moorings, you could see the dark mouth of a cavelike entrance to a four-acre submarine complex carved into the side of a mountain.

The Cold War relic, a top secret military installation under Soviet rule, was now a museum. Tourists could file past the 150-ton nuclear-blast-proof titanium doors, walk through tunnels, and peer into chambers where nuclear warheads had been stored. The deadly game of flinch between the two superpowers seemed far removed from the Crimean champagne a waiter was pouring.

"Deputy Zatulin," I asked, "do you know what Catherine the Great wrote Potemkin after claiming Crimea? 'Seizing objects is never disagreeable to us; it's losing them we don't like.'"

"Catherine wrote something else," he replied, looking at me steadily. "Potemkin suffered several defeats; he wanted to withdraw. Catherine

*Wouldn't you say
Crimea is now
the wart on
Ukraine's nose?
"Not a wart. A
festering carbuncle."*

—LEONID KRAVCHUK

wouldn't hear of it. 'To have Crimea and give it up is like riding a horse, then dismounting and walking behind the tail,' she told him.

"Well, we've given it away." He scowled. "The question is under what conditions it will continue to exist."

The same question was being asked in Kiev by the opposition. "Russia doesn't need its fleet in Sevastopol," a former minister of defense had said with barely suppressed anger. "It's just there to create instability."

Zatulin practically curled his lip when I quoted the former minister.

"The government that terminates the lease will have to answer the question of where to buy cheaper gas," he said.

Will the Russian fleet ever leave? I pressed. And when?

Zatulin, a man with a broad, florid face and thick build, picked up a red mullet from a platter of grilled fish and snapped its head off.

"My personal opinion? Never."

Write the truth, Galina kept urging—the Russian word is *pravda*—but truth wasn't easy to sound out, not with the colliding dreams of Ukrainians, Russians, and Tatars. Conventional wisdom held that violent conflict between Russia and Ukraine over Crimea was unimaginable because of close cultural and historical ties, especially now that Yanukovich had made Russia Ukraine's new best friend by extending the lease. It was tempting, but simplistic, to assume Yanukovich was Vladimir Putin's man in Kiev. The election had been fair, under the Yanukovich administration parliament had voted to take part in NATO military exercises, and Ukraine

still hoped to join the European Union. Nonetheless, uneasiness lingered.

"I was in Red Square in Moscow on Victory Day," Leonid Kravchuk told me. Kravchuk, Ukraine's first president, had deftly made the transition from Communist Party boss to leader of an independent democracy. Now, resolutely Ukrainian, he was wary of the Kremlin. "I tell you, I have seen many parades in my day. I have never seen one like this." He meant the turned-up volume on the demonstration of power.

Worries that Crimea could be the next flash point between Russia and its former satellites had faded with the resetting of Kiev's foreign policy, but Kravchuk thought a replay of the 2008 conflict when Russia sent tanks into Georgia (to protect its citizens, said the Russian government, though some suggest it was a reach for power in former territories) was not out of the question. "Such a thing is still possible," he said. "Russia knows what it wants from Ukraine. Ukraine doesn't know what it wants from Russia."

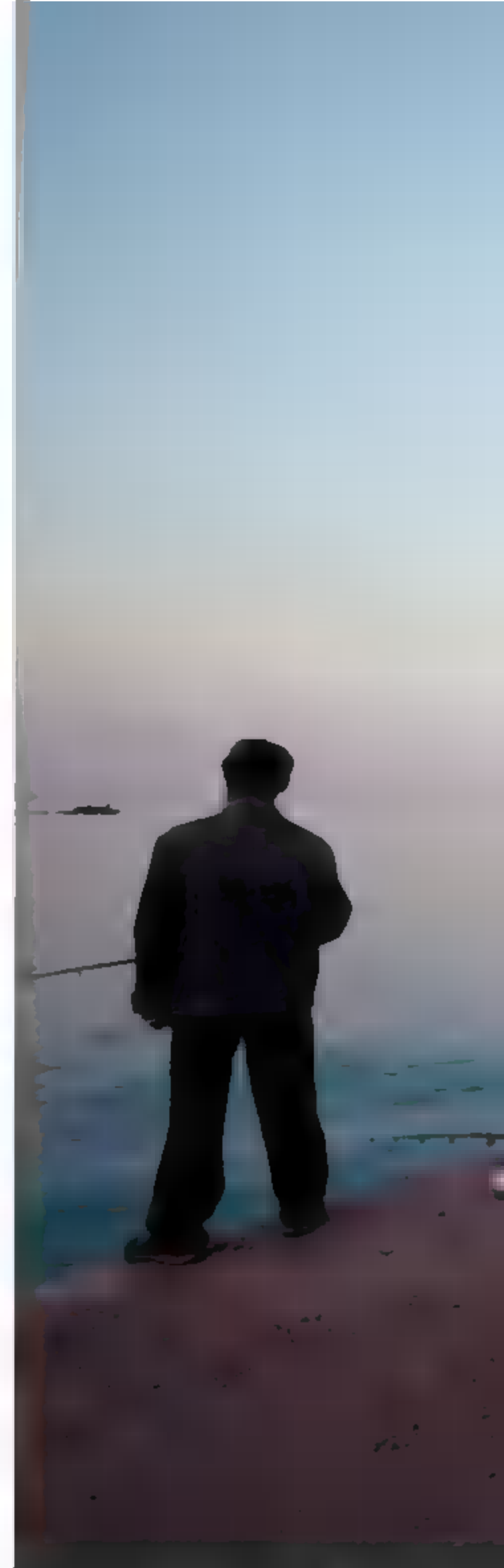
The best immunity against Russian intrusiveness seems to rest on Ukraine's ability to solidify its sense of self, but the road will be rocky, given the struggling economy and weak political traditions. True, Yanukovich had extinguished the sparks between Ukraine and Russia, but did Ukrainian Prime Minister Mykola Azarov really have to say, "Everything depends on the goodwill of Russians—we're like serfs." With public comments like the prime minister's it is small wonder that a national survey reported Ukrainians trust astrologers more than politicians.

On my last day in Crimea, I sat on a veranda overlooking Sevastopol Bay with Sergey Kulik, the Russian submarine officer turned Ukrainian think tank director. Across water the color of malachite, you could see the arc of temple-like government buildings rebuilt by Stalin after the war. "Sometimes when I get a visa to travel," said Kulik, "the consul looks at me as if to say, Are you coming back? Don't think for a minute I won't. I am Ukrainian. I will come back."

Kulik knew who he was. And the rest of

THE LURE OF FISHING

leads to a jetty in Alushta. Caught between its Russian past and its new identity as part of Ukraine, Crimea is still a work in progress. "We are babies just born," says Sevastopol lawyer Anatoliy Zhernovoy.



Crimea, not to mention Ukraine itself? Identity is problematic, said Oleg Voloshyn, press secretary to the foreign minister, because Ukraine was not a classical nation like England. Though most eastern European countries were patchwork entities, Ukraine was more fragmented than most, split as it had been in successive centuries between Russia and Poland, Russia and Austria, then between Russia, Poland, Czechoslovakia, and Romania, before finally becoming an independent state in 1991.

Crimea, it turns out, is as much a conundrum for Ukraine as it was for Russia. "Potemkin called Crimea the wart on Russia's nose," I reminded former Ukraine President Leonid Kravchuk at the close of our interview. Potemkin meant that Crimea was unruly; he worried Russia would never subdue the Tatars and gain control. "Instead of being the wart on Russia's



nose, wouldn't you say Crimea is now the wart on Ukraine's nose?" I suggested.

Kravchuk thought a bit. "Not a wart. A festering carbuncle."

Perhaps it will take another generation—several, even many—before Crimea defines itself as Ukrainian and not Ukrainian by default. Resisting change are those like Galina. On my last visit she told me she'd spent 100 hryvnia to have a new Soviet flag made, despite her heating-bill debt of 1,500 hryvnia.

"My flags will always stay with me," she said. "They inspire me and keep my spirits high." She carefully unfolded the banner with the hammer and sickle paid for with her pension money. It was nearly as long as her couch.

She seemed suddenly frail, sitting in her dark apartment in a pair of mismatched slippers, surrounded by the past—her flags (six Soviet Navy

flags, the tsar's flag known as the St. Andrew's, the newly acquired hammer and sickle banner), her grandfather's sword mounted on the wall, military medals, the sepia photograph of her husband in uniform, her father's sailor's tunic wrapped in tissue and mothballs.

"My great-grandfather, my grandfather, my father, my husband and son served in the fleet," she said. "And now, what do I have? A two-room flat and no money to pay for hot water."

The sword on the wall had tarnished. The sepia photographs were fading. The past, a political fairy tale of 78-kopek-a-kilo sugar and state-supported vacations, had vanished. The Iron Curtain had been torn down, and a nation was stumbling its way into the future.

"The sea is still with me, though," she said. "They did not take the Black Sea away. I can still go to the sea in the morning and swim." □

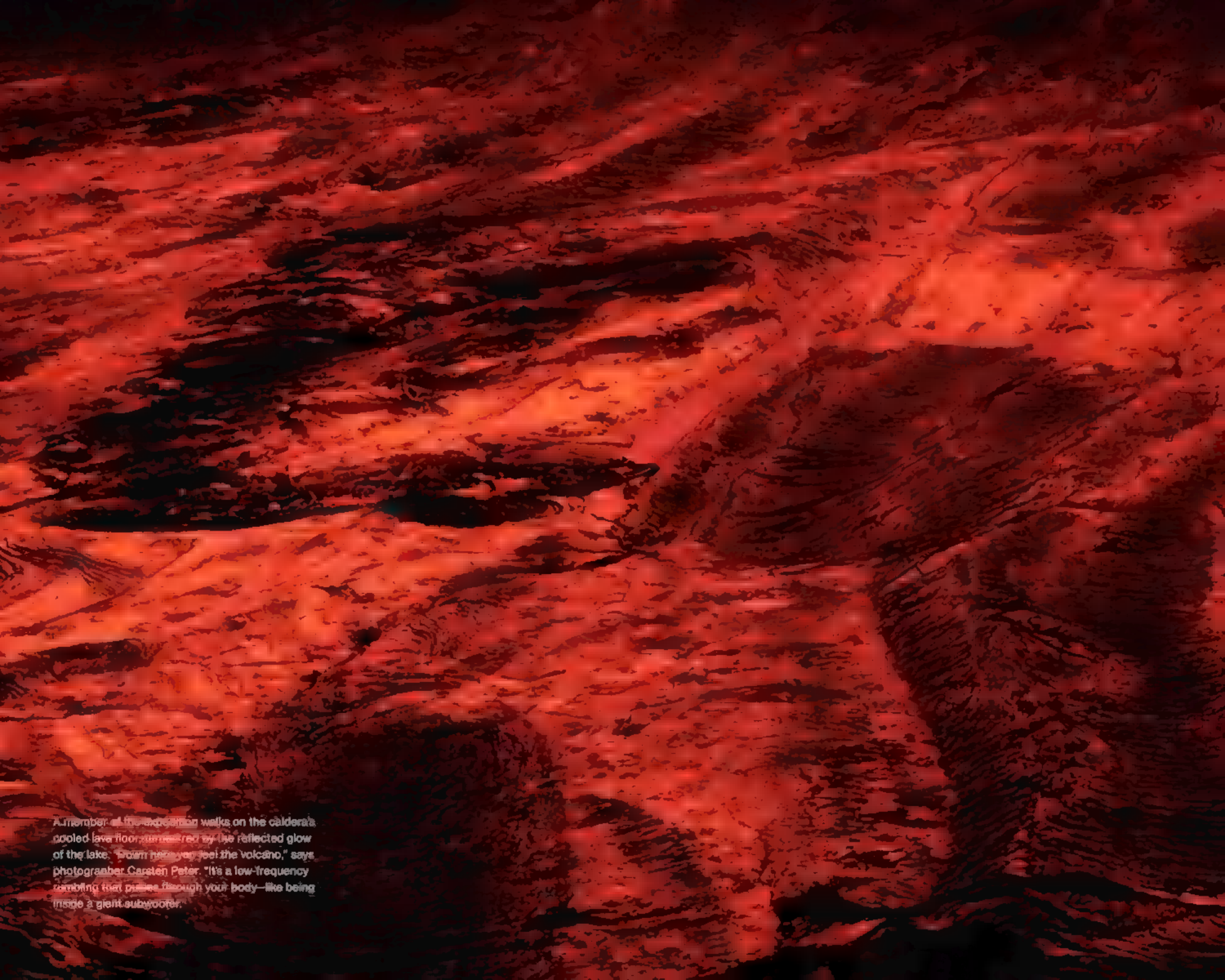


The Volcano Next Door

Scientists descend to a fiery lava lake
to protect a Congolese city in its path.



Cradling one of the world's largest and least studied lava lakes—more than 700 feet across and possibly miles deep—Nyiragongo has twice sent molten rock racing toward residents of Goma.



A member of the expedition walks on the caldera's cooled lava floor, immersed by the reflected glow of the lake. "From here you feel the volcano," says photographer Carsten Peter. "It's a low-frequency rumbling that passes through your body—like being inside a giant subwoofer."



BY MICHAEL FINKEL

PHOTOGRAPHS BY CARSTEN PETER



WHEN? THIS IS THE QUESTION THAT HAS BROUGHT TWO OF THE WORLD'S LEADING volcano scientists to the center of Africa; it's the question that haunts a team of Congolese seismologists; it's the question that may determine the fate of close to one million people. When will Nyiragongo erupt?

Nyiragongo is a two-mile-high volcano towering over the eastern edge of the Democratic Republic of the Congo (DRC)—one of the most active volcanoes on the planet and also one of the least studied. The chief reason for the lack of



Traders ferry logs and charcoal 12 miles from the forests around Nyiragongo to Goma, which continues to swell with refugees fleeing the Democratic Republic of the Congo's war-torn east. The plume rising from the mountain reminds residents of yet another threat: eruption.

research is that for the past 20 years the eastern DRC has seen nearly constant warfare, including a spillover of the massacres in neighboring Rwanda. One of the largest United Nations forces in the world, some 20,000 troops, currently maintains a fragile, and often broken, peace.

At the base of the volcano sprawls the city of Goma, growing by the day as villagers from the countryside seek refuge from rebel and government forces. An estimated million people are

now crammed into Goma. Twice in recent years Nyiragongo's eruptions have sent molten rock flowing toward the city. In 1977 lava raced down the mountain at more than 60 miles an hour, the fastest ever observed. Several hundred people died, even though the flow had hardened before it reached the main part of the city. In 2002 the volcano shot more than 15 million cubic yards of lava into downtown Goma, destroying 14,000 homes, burying buildings to the top of the first floor, and forcing 350,000 citizens to flee. Both eruptions were mere grumbles, though, compared with the fury Nyiragongo is thought capable of unleashing.

Part of Dario Tedesco's job is to envision that possibility. For much of the past 15 years, with funding from the European Union, the Italian volcanologist has struggled to focus the scientific community's attention on Nyiragongo. According to Tedesco, there is no question the volcano will erupt again, potentially transforming Goma into a modern Pompeii.

"Goma," he says, "is the most dangerous city in the world."

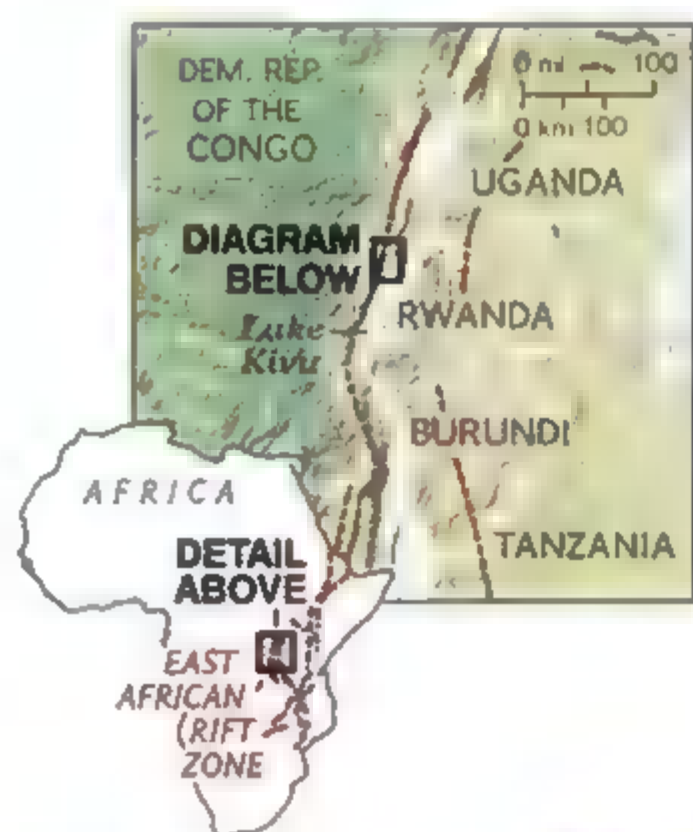
Last July, Tedesco headed to Nyiragongo with U.S. volcanologist Ken Sims, a team of younger scientists, and a support crew, including six Kalashnikov-toting guards. Their three-week mission was akin to that of a doctor giving a patient a long-overdue physical exam. They wanted to take the measure of the mountain, to study its rocks and sample its gases, to decipher its methods and moods. They hoped to transform the question of when into the beginnings of an answer.

REACHING THE SUMMIT rim of Nyiragongo was straightforward: Sims and Tedesco followed the lava. The recent eruptions hadn't been classic, spouting-out-the-top types, so-called Plinian eruptions, but rather fissure eruptions, like bursting pipes. In 2002 the rupture happened a few hundred feet below the 11,385-foot peak.

Michael Finkel last wrote about the Hadza of Tanzania. Carsten Peter's photos of giant cave passages in Vietnam appeared in our January issue.

Threat Zone

Close to one million people in the Lake Kivu Basin have potentially lethal neighbors: a lake full of deadly gases, lava-spewing cones and fissures, and active volcanoes. All were created by titanic forces pulling apart the East African Rift Zone.

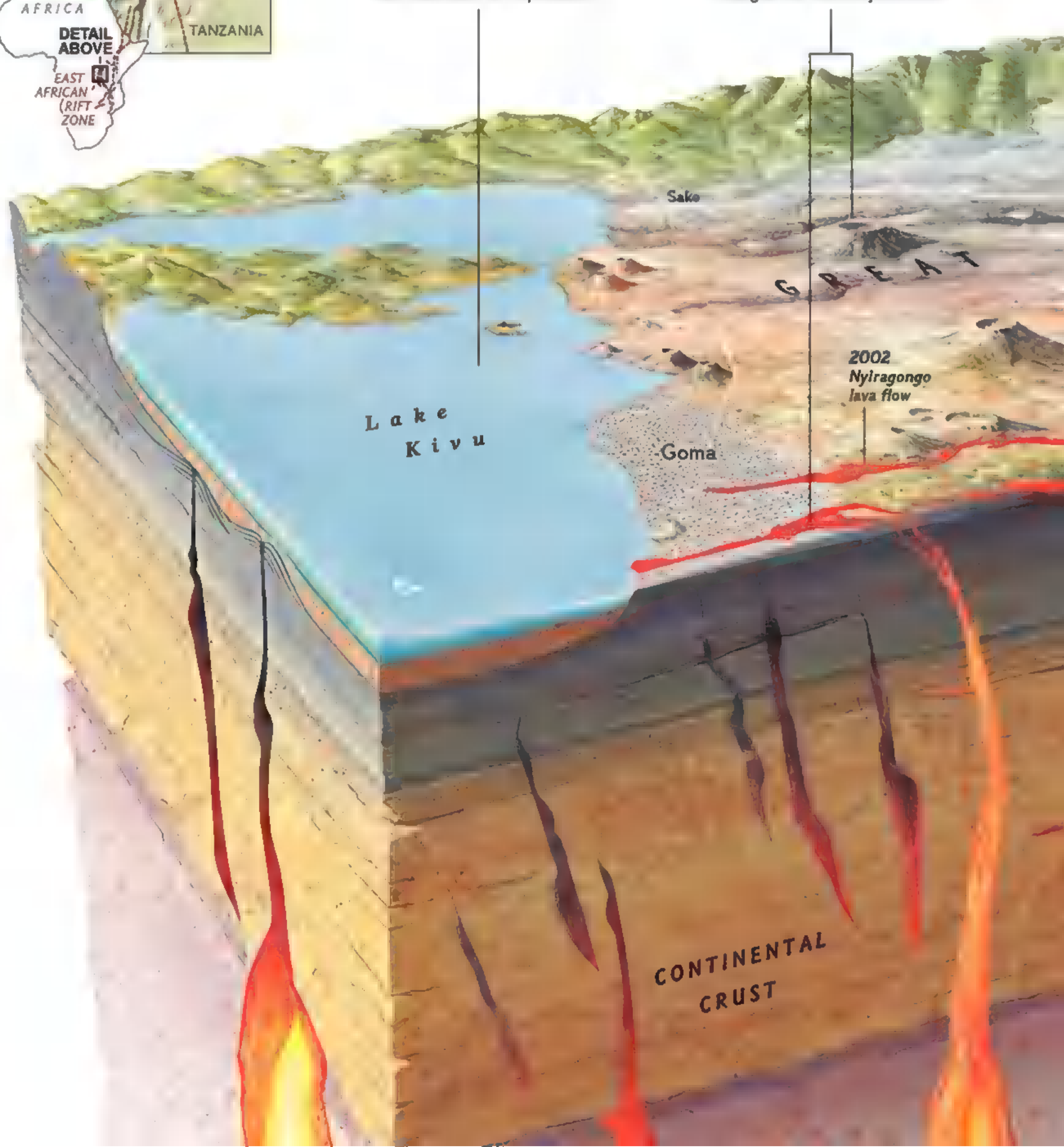


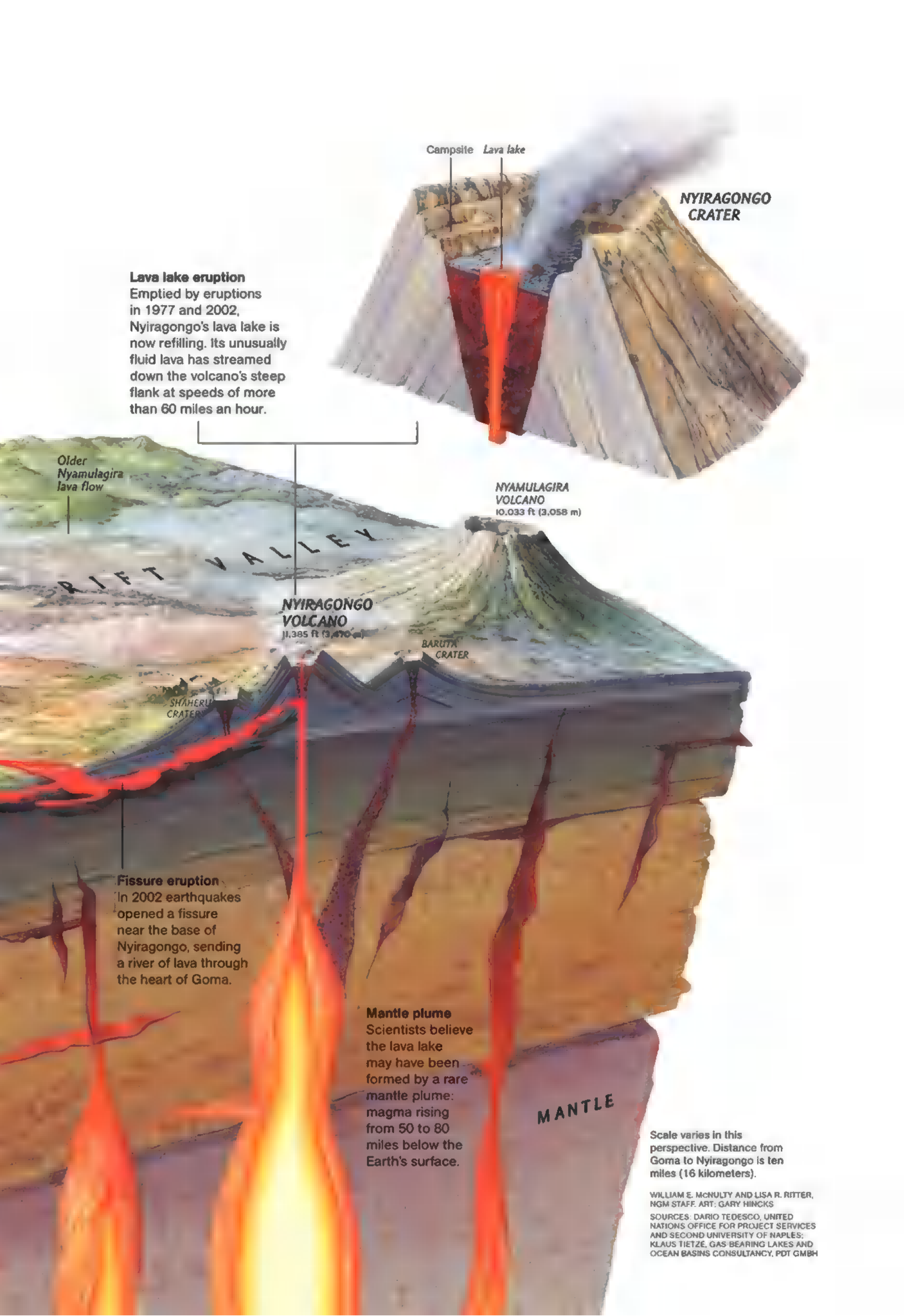
Killer gases underwater

Trillions of cubic feet of dissolved methane and carbon dioxide have collected in the lake's waters. A major quake or eruption could release a deadly cloud of gases, generate a tsunami, and even set off explosions.

Baby volcanoes

The region is riddled with fissures both at the surface and underground. Some have formed parasitic cones—secondary vents to magma below. Though small, they could belch enough lava to destroy villages and cut major roads.





Lava lake eruption
Emptied by eruptions in 1977 and 2002, Nyiragongo's lava lake is now refilling. Its unusually fluid lava has streamed down the volcano's steep flank at speeds of more than 60 miles an hour.

Older Nyamulagira lava flow

NYAMULAGIRA VOLCANO
10,033 ft (3,058 m)

NYIRAGONGO VOLCANO
11,385 ft (3,470 m)

BARUTA CRATER

SHAHERU CRATER

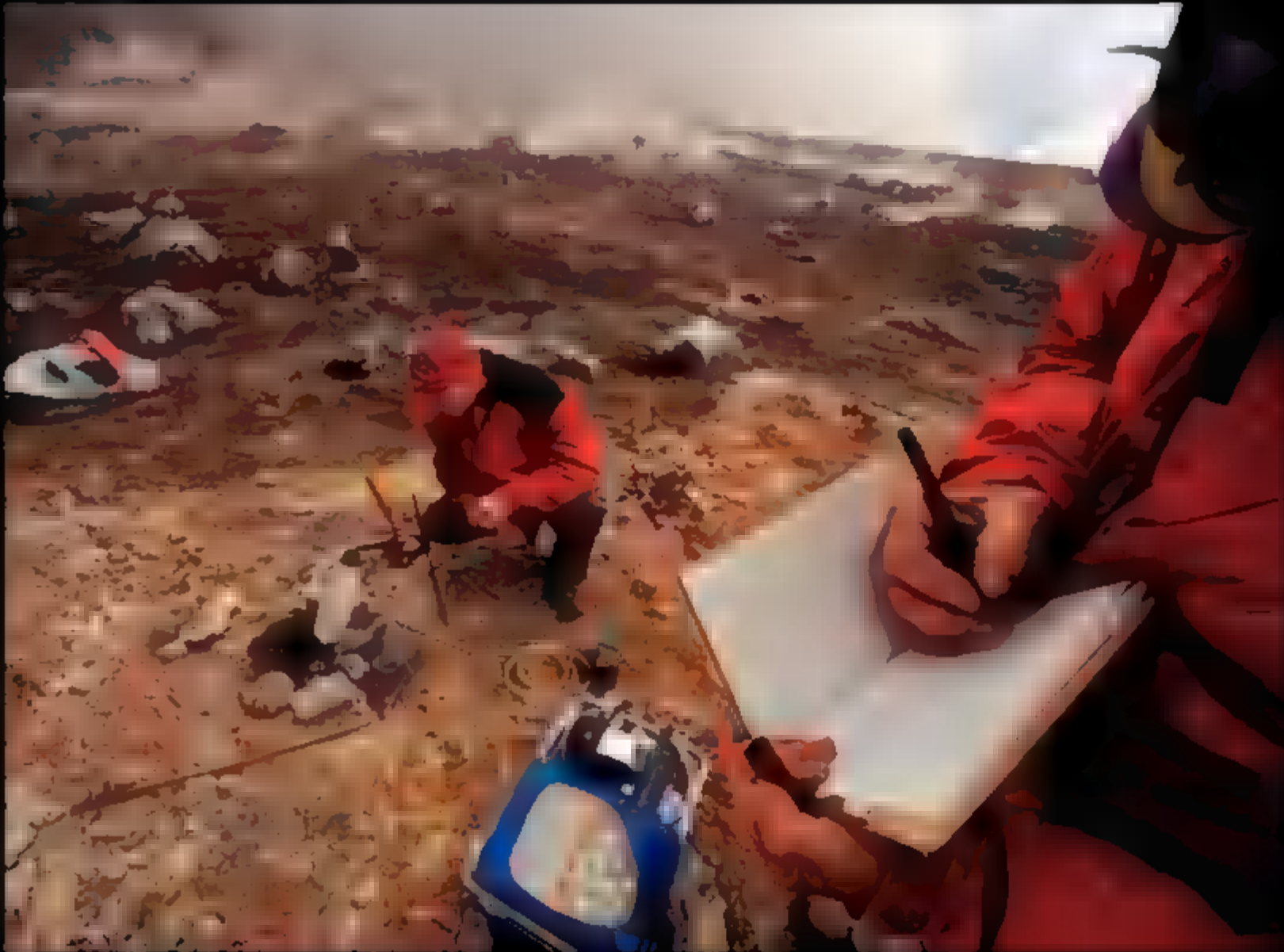
MANTLE

Fissure eruption
In 2002 earthquakes opened a fissure near the base of Nyiragongo, sending a river of lava through the heart of Goma.

Mantle plume
Scientists believe the lava lake may have been formed by a rare mantle plume: magma rising from 50 to 80 miles below the Earth's surface.

Scale varies in this perspective. Distance from Goma to Nyiragongo is ten miles (16 kilometers).

WILLIAM E. McNULTY AND LISA R. RITTER, NGM STAFF. ART: GARY HINCKS
SOURCES: DARIO TEDESCO, UNITED NATIONS OFFICE FOR PROJECT SERVICES AND SECOND UNIVERSITY OF NAPLES; KLAUS TIETZE, GAS-BEARING LAKES AND OCEAN BASINS CONSULTANCY, PDT GMBH





Clouds of toxic gas and frequent tremors were two of the challenges faced by a team of scientists led by Dario Tedesco and Ken Sims (top left) as they studied Nyiragongo's crater. All the team's food, water, and gear had to be hauled to the summit rim by porters, many of them local women (bottom left), and then lowered by pulley into the caldera (above). The biggest threat was falling rocks, Sims says. "The caldera is continually collapsing on itself."

Nyiragongo has an intricate plumbing system, widespread as the roots of a tree, and once the initial seam opened, the pressure blew open vents systemwide, shooting out fountains of molten rock, including in the very center of town. The risk, it turns out, is not just near the city of Goma, but directly beneath it.

The lava had steamrolled through forests and neighborhoods. It looked as if a ten-lane highway had been dropped down the mountain's flanks, right across the city. Though the next eruption will likely follow a similar path, thousands of homes, shacks of hand-hewn eucalyptus boards and sheet-metal roofs, have been built directly atop the old flow. Real estate brokers sell tiny lots consisting of nothing but lava rocks enclosed by lava walls for as much as \$1,500. And if Goma doesn't have enough to worry about, the thousand-square-mile Lake Kivu conceals an enormous underwater concentration of carbon dioxide and methane. The theory is that a major eruption could release it, spreading a lethal cloud across the city that would spare no one.

After a full day of hiking, Sims and Tedesco reached the barren, wind-wracked summit rim. A long line of porters hauled camping gear, climbing equipment, scientific instruments, food, and water. From here, the scientists looked into the mouth of the volcano. Crumbly sheer walls ringed by ledges dropped a quarter mile down to a vast, flat floor, black with hardened lava. In the middle, contained in a giant soup-bowl-shaped spatter cone, was a stunning sight: a lake of lava.

The lake was 700 feet across—one of the largest in the world—with a mesmerizing kaleidoscopic surface. Black plates were cut by jagged cracks of orange, violently shifting and roiling. One moment the crust took the form of a shattered windshield, then it coalesced into a jigsaw puzzle, then a ragged map of the world. The lake roared like a jet plane taking off and emitted a thick white plume of dozens of deadly gases. "The whole periodic table is churning in there," Sims said.

Society Grant This expedition was funded in part by your National Geographic Society membership.

Even from the rim the scientists could feel the heat. The 1800°F lava exploded from the lake in electric orange geysers, several every minute—25 feet high, 50 feet, 100 feet, bursting into evanescent arches of liquid rock morphing from orange to black in midair as they cooled. The lake seemed to breathe, expanding and contracting, rising and falling, its surface level changing several feet in a matter of minutes, spectacular and terrifying at once.

Sims was awestruck. "There," he said after a long silence, pointing down at the lake, "is where I'd really love to get a sample."

SIMS IS 50 YEARS OLD, an avid rock climber and former professional mountain guide. He doesn't like cities; he's allergic to crowds. He dresses as if life were one long camping trip. A professor at the University of Wyoming, he lives in Laramie with his wife and two young children. He hasn't owned a TV set in 25 years. Volcano science has never been a safe occupation—more than 20 scientists have died on volcanoes in the past 30 years. Sims carries a scar on his right arm from Sicily's Mount Etna, where his shirt melted into his skin. He's even-tempered and analytical and seemingly never off duty. He once wrote a paper on a restaurant tablecloth, scribbling until 3 a.m. Then he took the tablecloth home.

Tedesco, 51, is fiery and fashion conscious, an inexperienced alpinist and an unrepentant epicure. On the Nyiragongo expedition, where every ounce hauled up the mountain was carefully considered, Tedesco brought a large glass bottle of extra virgin olive oil. He lives with his wife, teenage daughter, five cats, and three dogs just outside Rome and is a professor at the Second University of Naples. When he speaks of Nyiragongo, he drops all pretense of scholarly dispassion. "It's no secret that I love Goma," he says. "My greatest fear is to make a big mistake—not to predict an eruption."

Sims led the descent into the crater, anchoring ropes and spidering down walls. The rest of the party followed. Nyiragongo is in the Great Rift Valley, where the African continental plate is being wrenched apart, and microquakes constantly

shake the volcano. Pebbles clattered down walls. Town-house-size rocks wobbled like loose teeth. The mountain seemed ready to collapse.

The team set up camp on a wide ledge 800 feet below the rim, a few hundred feet above the thundering lake. The ledge was covered with heavy ash, called tephra, and speckled with droplets of volcanic glass and delicate lava threads known as Pele's hair. The surface was warm; hiking pants left on a tent floor had a fresh-from-the-dryer feel in the morning.

Every day the lava lake emits around 7,000 tons of sulfur dioxide, the chief element in acid rain. This is more than the total from every car and factory in the United States. "Basically, it's one big chimney," Tedesco said. The environment was noxious, the air full of acid and metallic aerosol particles. Raindrops sizzled as they landed in fumaroles. Gas masks were worn. Within days, zipper pulls corroded; camera lenses began disintegrating. Sims handed out throat lozenges.

Here on this ledge Tedesco and Sims began working with the field lab they'd brought. A blue padded case held what Tedesco called a "gas sniffer" to measure carbon dioxide, carbon monoxide, and methane. A shoe-box-size RAD7 tested for radon. A vacuum pump, housed in a rusty ammo box, captured a fumarole's plume.

Why measure gas? Because volcanoes are gas-driven machines. An eruption is often preceded by an increase in discharged gas and by variations in its chemical composition. The rise of magma, its accumulation in chambers, its propulsion into fractures—these events produce chemical signals that reach the surface well ahead of the magma itself.

Sims uses radioactive clocks to decipher volcanic processes, measuring and comparing two isotopes of radon. By tracking this ratio over time, he can determine how long gas has taken to reach the surface and gain clues to the chemical, thermal, and mechanical state of the rocks the gas is passing through. But few conclusions can be derived from a single expedition. Only long-term studies can determine which type of gas fluctuations are cause for alarm and which are part of the volcano's normal cycles. Until

He peeked over the top, eye to eye with the boiling lava. This was beyond science. This was personal.

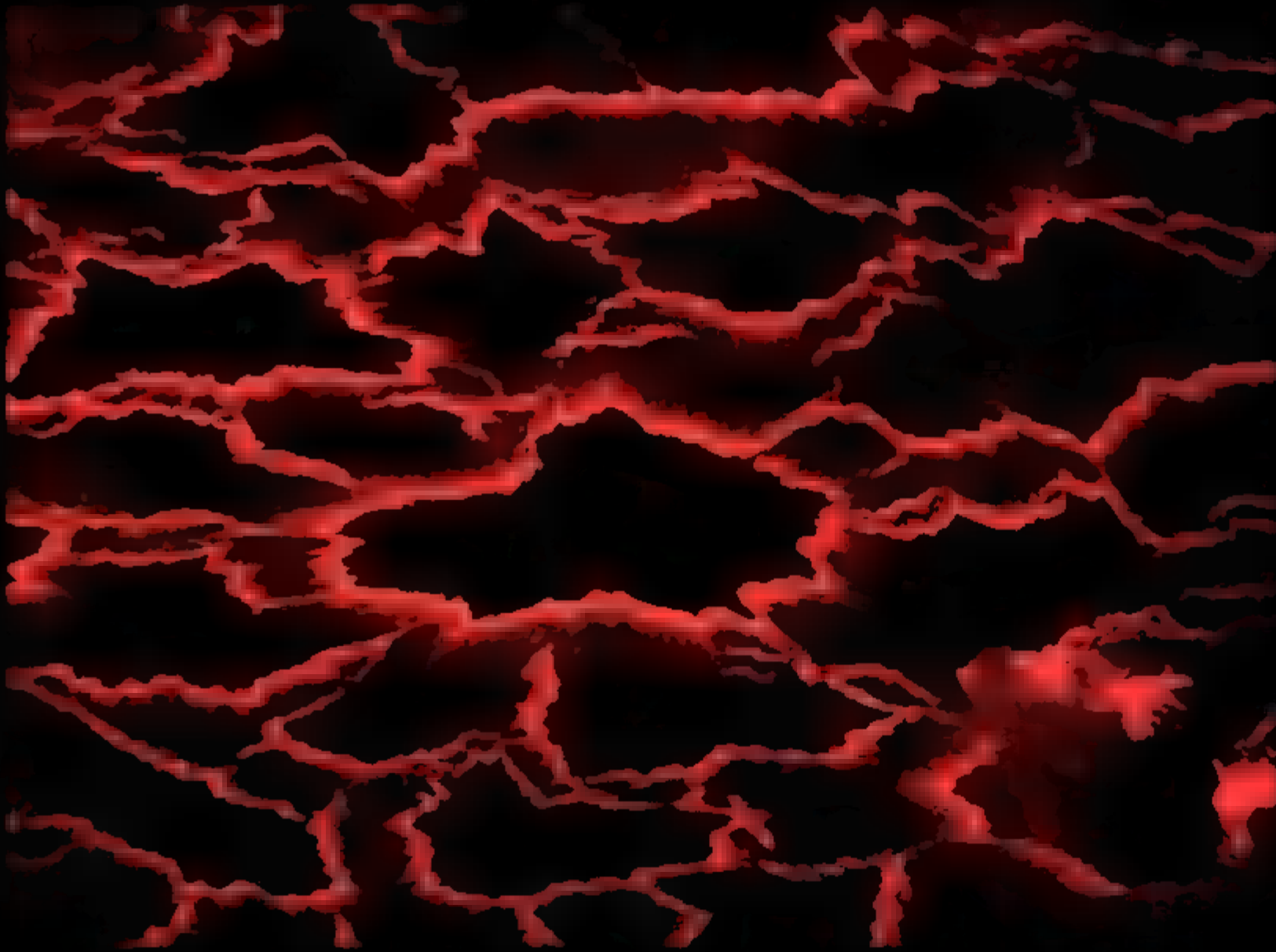
top scientists make regular visits—something Tedesco has been desperately urging—the best that can be done is to maintain a precise record of Nyiragongo's every move.

That task falls to the Goma Volcanic Observatory, located in a dilapidated one-story building in the city center and staffed around the clock. Katcho Karume, 44, the observatory's director general, has a Ph.D. in environmental physics. "Seismology is the heart of what we do," he said. Swarms of tremors are usually, though not always, a sign that an eruption is coming. But many of the observatory's seismic stations on Nyiragongo's slopes were looted during the wars. "For batteries," said Karume, shaking his head at the thought that Goma's population could be decimated for a few dollars' worth of batteries.

"You know, I hardly sleep," said Karume. "One million people depend on us." Without modern equipment, which could cost two million dollars—a daunting sum in one of the poorest nations in the world—an accurate forecast might not be possible. And even if the observatory were able to predict an eruption, then what?

"There is an emergency plan," insisted Feller Lutaichirwa, vice governor of North Kivu Province. Warning flags at stations throughout town, he said, announce the risk level of an eruption, from green, indicating low danger, to red, meaning an eruption is imminent.

Others begged to differ. "There is no plan," said journalist Horeb Bulambo. "And the flags are old." He was right. At most of the stations I saw, every flag had faded to white. Esteban Sacco, who until recently operated Goma's United Nations humanitarian affairs office, mentioned that only





With temperatures around 1800°F, the lava lake is wildly erratic. As molten rock meets the air, it cools and forms plates on the lake's surface (top left). Rising gas bubbles often explode and can splatter lava some 60 feet in the air (bottom left), sending waves of lava lapping over the rim (above). Scientists aren't sure of the lake's depth, though recent lava samples indicate the magma originated in the Earth's mantle more than 46 miles below.

one road leads out of the city away from the volcano. "Within a couple of hours the whole town will be stuck," he said. "Imagine the worst."

Meanwhile, people continue to live on top of the lava. "I saw the eruption in 1977 and again in 2002," said Ignace Madingo, administrative secretary of the city district closest to the volcano. Both times he fled with his family, and both times his house disappeared. "Many people from this area died," he said. "The lava turned them into stones. You can't imagine. You never see them again. No trace." Today his land is a pile of jagged volcanic rocks. "We know the mountain will erupt again. Lava will come. Our houses will burn. And after, we will build once more."

TO PREVENT A CATASTROPHE, Sims believes, we must gain a deeper understanding of Nyiragongo. For starters, one crucial source of information is what's known as a zero-age sample: a chunk of lava fresh from the lake. It would be the Rosetta stone of Nyiragongo, the piece that could unlock the mountain's story, allowing every other rock to be accurately dated. "Ultimately it could lead to better eruptive predictions," Sims said.

Sims wanted that lava chunk. But he knew retrieval would be dangerous, and he struggled with the decision. He thought of his family; he fretted over lava bombs and rockfalls. He would never allow one of his own students to risk his or her life for such a sample. Yet he also understood that he was one of only a few people with both the climbing skills and scientific knowledge to get exactly what he wanted.

So he rappelled into the heart of the volcano. Standing on the crater floor, he couldn't see the lake itself, which was above him within the cone of cooled lava. But he could hear its hissing gases and smell its acrid fumes. He pulled on a silver-colored thermal suit, like a full-body oven mitt, so rigid he couldn't bend over to tie his shoes.

As he approached the spatter cone, the lava crunched like eggshells beneath his feet. The rim was 40 feet high, the wall nearly vertical, requiring rock-climbing skills to ascend. He started up, stretching for handholds and foot placements, drenched in sweat inside the suit. When he was

Photographer Carsten Peter tests the thermal suit that Ken Sims used to get close to the lava lake. "It can protect you from the radiant heat, but if you get hit with a lava splatter, the force will likely kill you," he says. For 30 years Peter has explored volcanoes around the world.

"Seeing at close range the primal forces that shaped the planet can be hypnotic," he says. "You cannot allow yourself to fall under a volcano's spell, especially one as unpredictable as Nyiragongo. That can be a fatal mistake."

ten feet from the top, spotters described to him over the radio the level of the lava, where it was exploding, where it was spilling over. Conditions changed by the minute. He was five feet away. Then three. Suddenly his foot slipped, and he smelled burning rubber. Looking down, he saw his shoe melting out from under him.

But he kept going. He peeked over the top, eye to eye with the boiling lava. This was beyond science. This was personal, the culmination of a





lifetime of exploration and adventure and tireless curiosity. Over the radio the emotion in his voice was palpable. “Amazing. Incredible. I’ll never see anything like this again.”

After a few seconds he backed away. There was still essential work to do. He didn’t have a hammer, so with a hard slam of his fist he broke off a piece of fresh lava. It was shiny, iridescent black, and so hot that, even wearing thermal gloves, he juggled it from hand to hand.

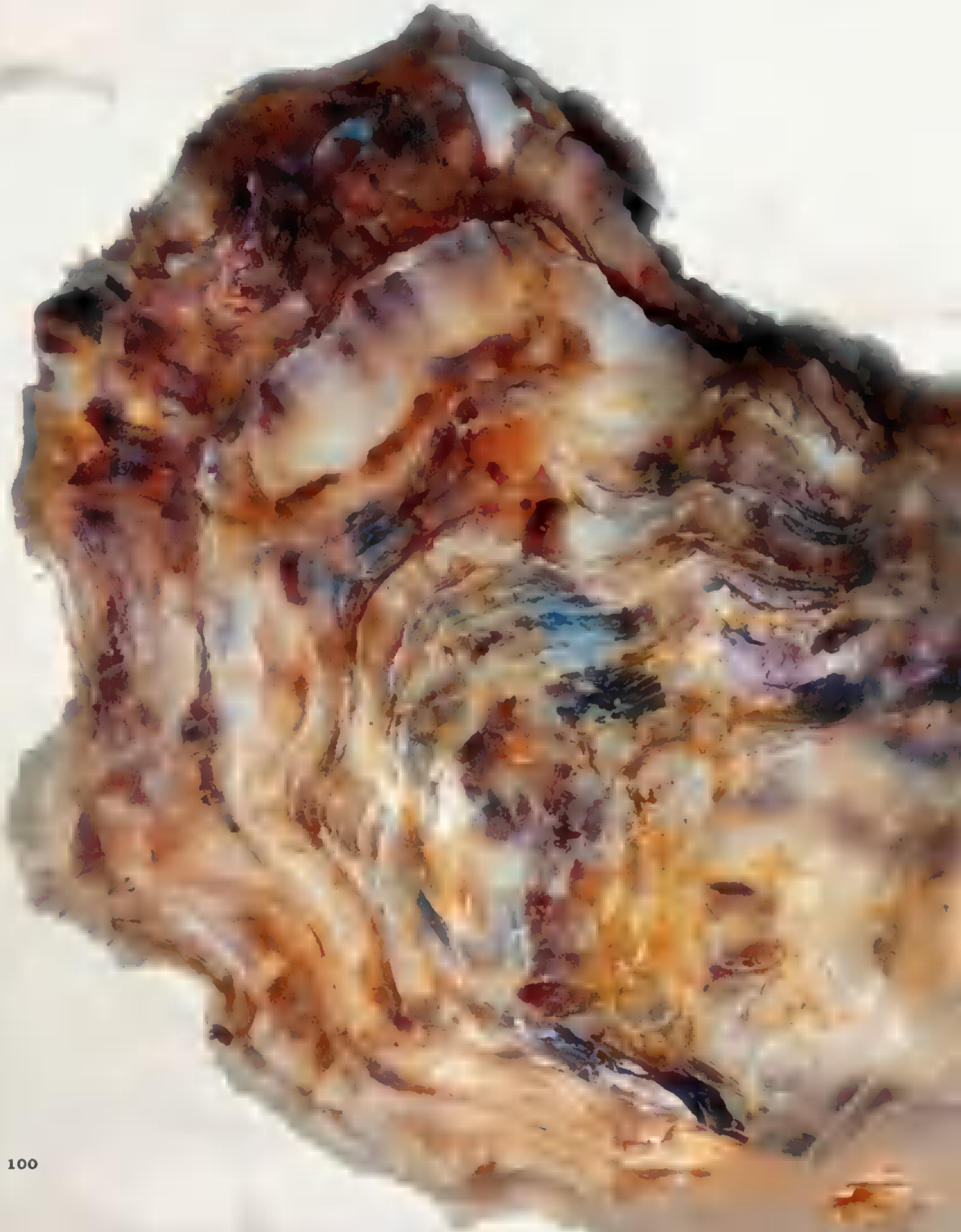
But he had it. The zero-age sample. Through a war zone, up a mountain, down a crater, to the edge of a lava lake, he had it. Now the science, at long last, could begin. □



RISKY RESEARCH

Carsten Peter and team drop into Nyiragongo in *Man vs. Volcano*, on the **National Geographic Channel**, April 7 at 10 p.m. ET/PT in the U.S.

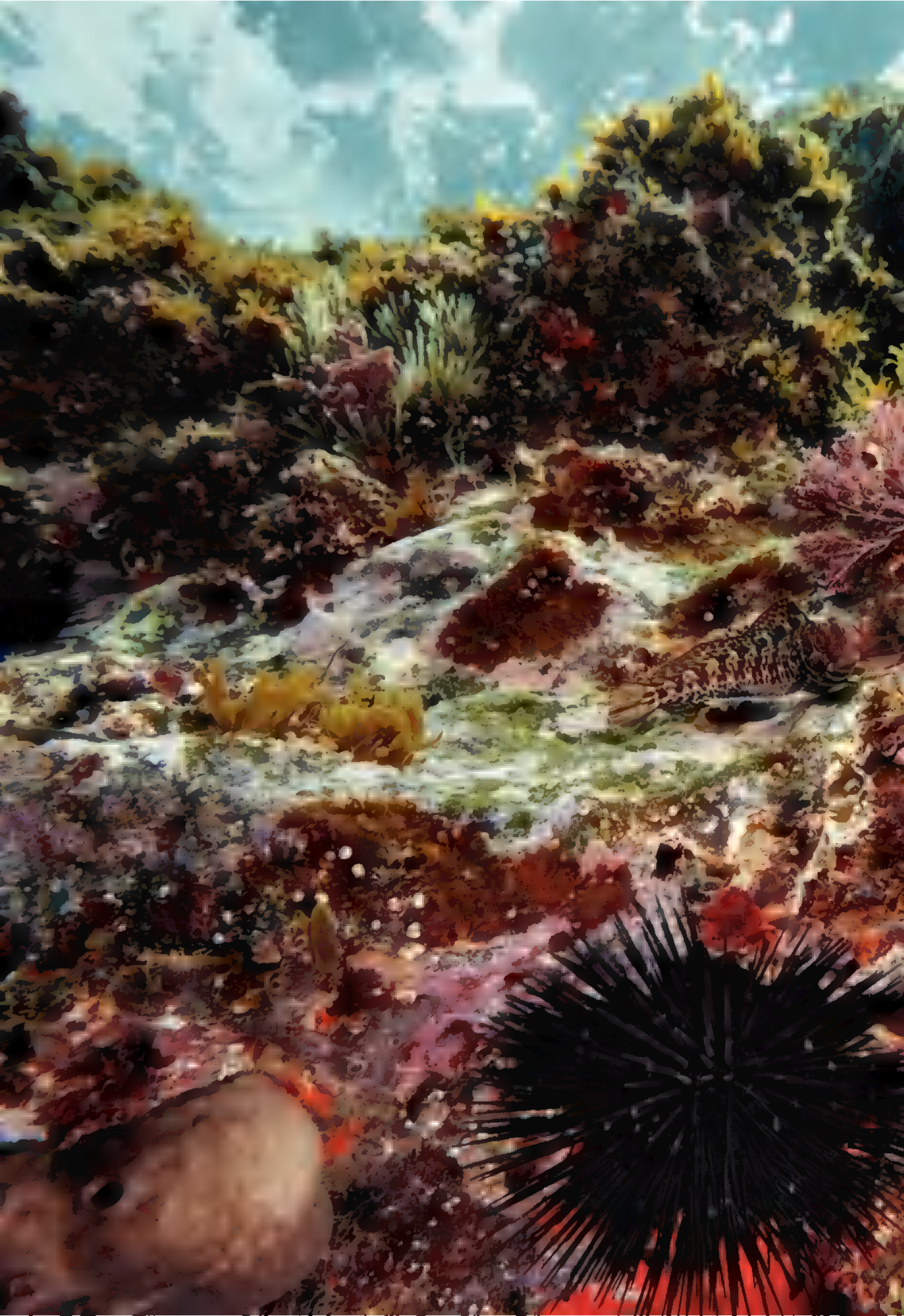
A Pacific oyster releases its cloudy sperm at Oregon's Whiskey Creek Shellfish Hatchery. In some coastal waters acidification is already severe; here it has cut production in half by stunting oyster larvae.





THE ACID SEA

The carbon dioxide we pump into the air is seeping into the oceans and slowly acidifying them. One hundred years from now, will oysters, mussels, and coral reefs survive?

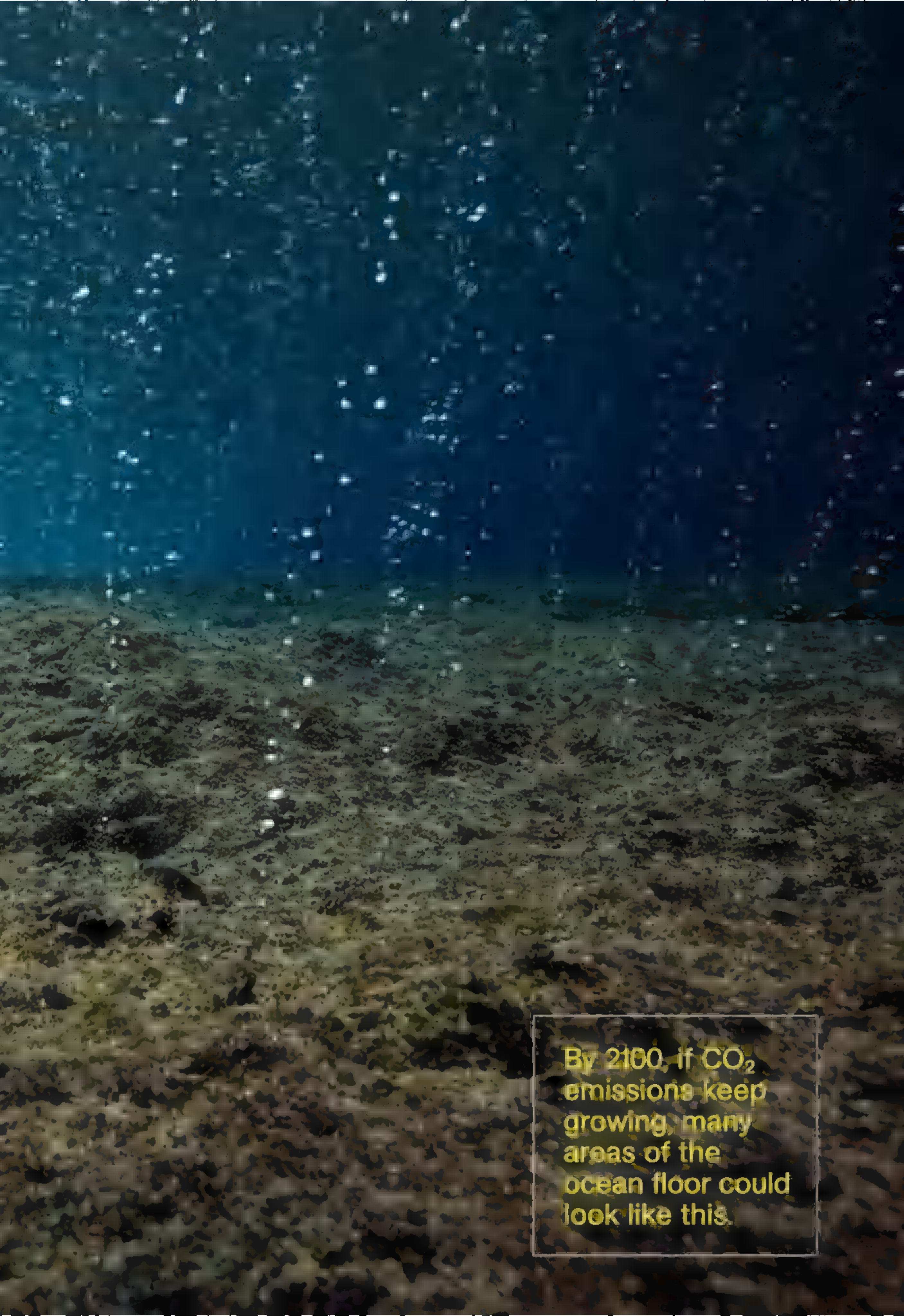




At Castello Aragonese, a volcanic island off Naples, Italy, healthy seafloor looks like this: a lumpy quilt of red sponges, white barnacles, lilac coralline algae, sea urchins, and (near the center of the photograph) one well-camouflaged fish. It's a tompot blenny.



A few hundred yards from the preceding scene, CO₂ bubbling from seafloor vents acidifies the water to levels that might one day prevail all over the oceans. Dull mats of algae replace the colorful diversity—“the warming,” says biologist Jason Hall-Spencer.



By 2100, if CO₂ emissions keep growing, many areas of the ocean floor could look like this.

BY ELIZABETH KOLBERT PHOTOGRAPHS BY DAVID LIITTSCHWAGER

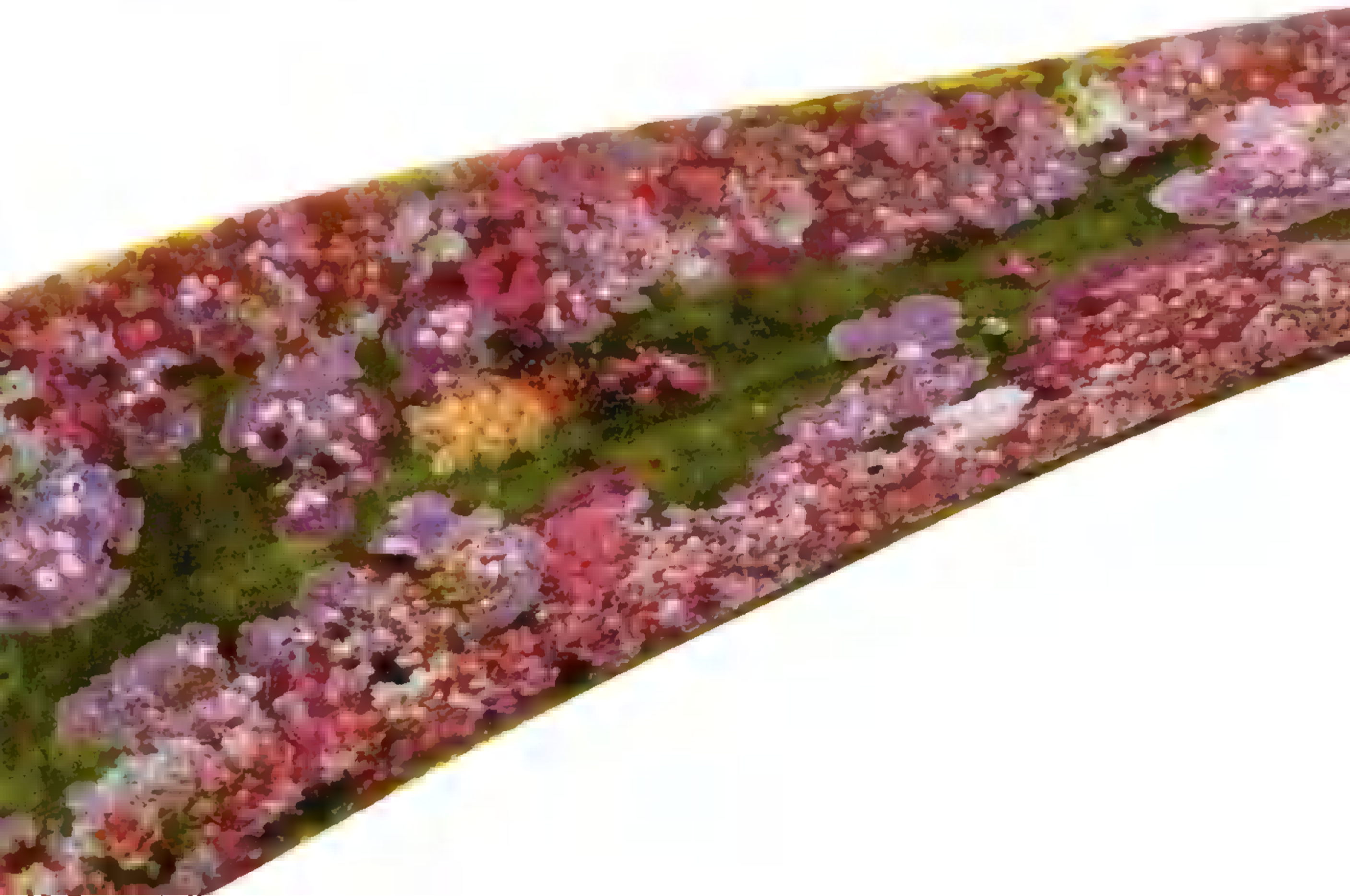
CASTELLO ARAGONESE IS A TINY ISLAND that rises straight out of the Tyrrhenian Sea like a tower. Seventeen miles west of Naples, it can be reached from the somewhat larger island of Ischia via a long, narrow stone bridge. The tourists who visit Castello Aragonese come to see what life was like in the past. They climb—or better yet, take the elevator—up to a massive castle, which houses a display of medieval torture instruments. The scientists who visit the island, by contrast, come to see what life will be like in the future.

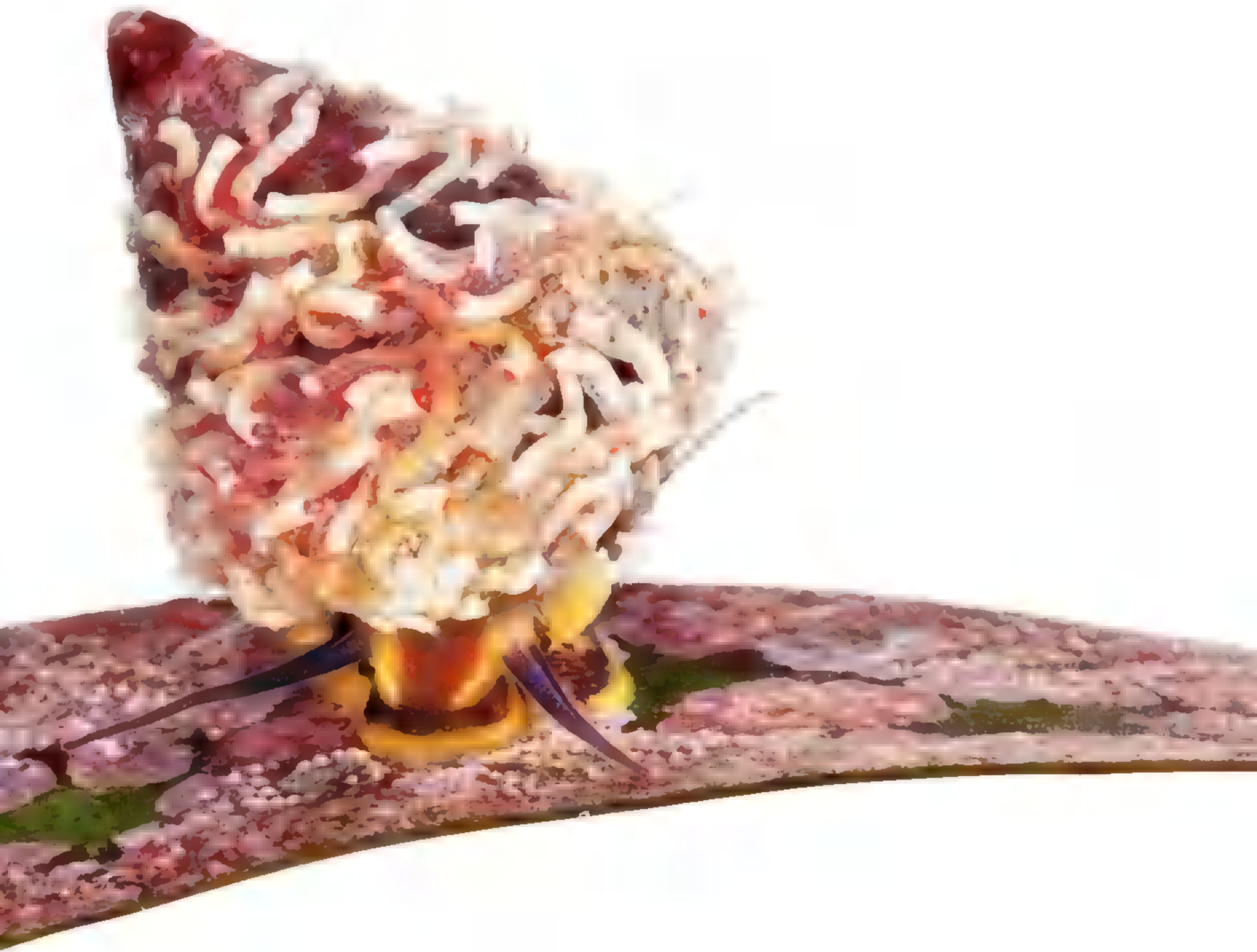
Owing to a quirk of geology, the sea around Castello Aragonese provides a window onto the oceans of 2050 and beyond. Bubbles of CO₂ rise from volcanic vents on the seafloor and dissolve to form carbonic acid. Carbonic acid is relatively weak; people drink it all the time in carbonated beverages. But if enough of it forms, it makes

seawater corrosive. “When you get to the extremely high CO₂, almost nothing can tolerate that,” Jason Hall-Spencer, a marine biologist from Britain’s University of Plymouth, explains. Castello Aragonese offers a natural analogue for an unnatural process: The acidification that has taken place off its shore is occurring more gradually across the world’s oceans, as they absorb more and more of the carbon dioxide that’s coming from tailpipes and smokestacks.

Hall-Spencer has been studying the sea around the island for the past eight years, carefully measuring the properties of the water and tracking the fish and corals and mollusks that live and, in some cases, dissolve there. On a chilly winter’s day I went swimming with him and with Maria Cristina Buia, a scientist at Italy’s Anton Dohrn Zoological Station, to see the effects of acidification up close. We anchored our boat about 50 yards from the southern shore of

SEVEN BILLION is a yearlong series on global population.





A blade of sea grass at Castello Aragonese is a microcosm. Coralline algae cover the blade, a snail grazes on the algae, tube worms colonize the snail. All three make calcium carbonate. Near the CO₂ vents, however, the grass is green, stripped of its companions—because acidification has stripped the water of carbonate.

Castello Aragonese. Even before we got into the water, some impacts were evident. Clumps of barnacles formed a whitish band at the base of the island's wave-battered cliffs. "Barnacles are really tough," Hall-Spencer observed. In the areas where the water was most acidified, though, they were missing.

We all dived in. Buia was carrying a knife. She pried some unlucky limpets from a rock. Searching for food, they had wandered into water that was too caustic for them. Their shells were so thin they were almost transparent. Bubbles of carbon dioxide streamed up from the seafloor like beads of quicksilver. We swam on. Beds of sea grass waved beneath us. The grass was a vivid green; the tiny organisms that usually coat the blades, dulling their color, were all missing. Sea urchins, commonplace away from the vents, were also absent; they can't tolerate even moderately acidified water. Swarms of nearly transparent jellyfish floated by. "Watch out," Hall-Spencer warned. "They sting."

Jellyfish, sea grass, and algae—not much else lives near the densest concentration of vents at Castello Aragonese. Even a few hundred yards away, many native species can't survive. The water there is about as acidified as the oceans as a whole are forecast to be by 2100. "Normally in a polluted harbor you've got just a few species that are weedlike and able to cope with widely fluctuating conditions," Hall-Spencer said once we were back on the boat. "Well, it's like that when you ramp up CO₂."

SINCE THE START of the industrial revolution, enough fossil fuels—coal, oil, and natural gas—have been burned and enough forests cut down to emit more than 500 billion tons of CO₂. As is well known, the atmosphere has a higher concentration of CO₂ today than at any point in the past 800,000 years and probably a lot longer.

What is less well known is how carbon emissions are changing the oceans too. The air and the water constantly exchange gases, so a portion of anything emitted into the atmosphere eventually ends up in the sea. Winds quickly mix it into the top few hundred feet, and over

centuries currents spread it through the ocean depths. In the 1990s an international team of scientists undertook a massive research project that involved collecting and analyzing more than 77,000 seawater samples from different depths and locations around the world. The work took 15 years. It showed that the oceans have absorbed 30 percent of the CO₂ released by humans over the past two centuries. They continue to absorb roughly a million tons every hour.

For life on land this process is a boon; every ton of CO₂ the oceans remove from the atmosphere is a ton that's not contributing to global warming. But for life in the sea the picture looks different. The head of the National Oceanic and Atmospheric Administration, Jane Lubchenco, a marine ecologist, has called ocean acidification global warming's "equally evil twin."

The pH scale, which measures acidity in terms of the concentration of hydrogen ions, runs from zero to 14. At the low end of the scale are strong acids, such as hydrochloric acid, that release hydrogen readily (more readily than carbonic acid does). At the high end are strong bases such as lye. Pure, distilled water has a pH of 7, which is neutral. Seawater should be slightly basic, with a pH around 8.2 near the sea surface. So far CO₂ emissions have reduced the pH there by about 0.1. Like the Richter scale, the pH scale is logarithmic, so even small numerical changes represent large effects. A pH drop of 0.1 means the water has become 30 percent more acidic. If present trends continue, surface pH will drop to around 7.8 by 2100. At that point the water will be 150 percent more acidic than it was in 1800.

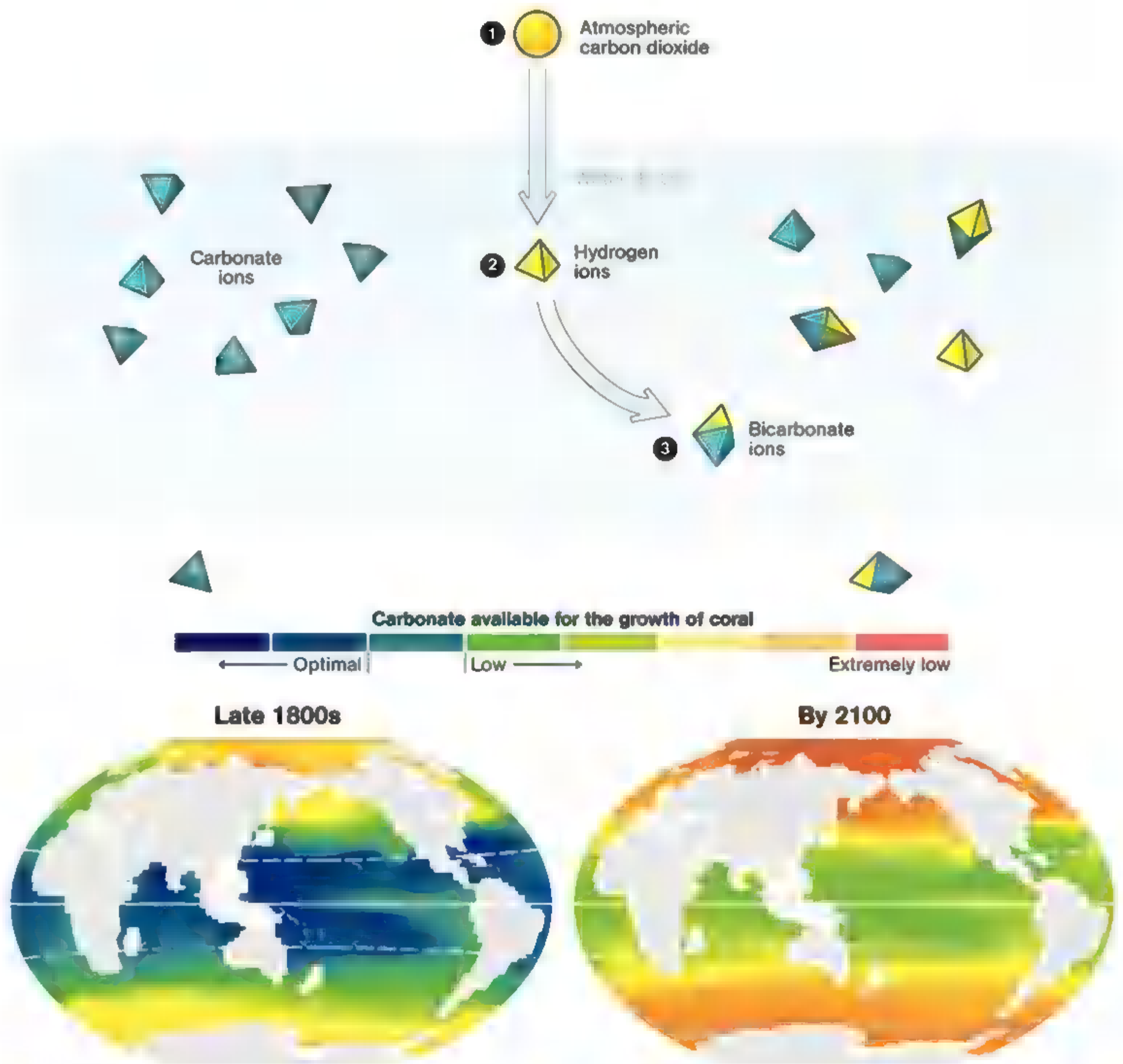
The acidification that has occurred so far is probably irreversible. Although in theory it's possible to add chemicals to the sea to counter the effects of the extra CO₂, as a practical matter, the volumes involved would be staggering; it would take at least two tons of lime, for example, to offset a single ton of carbon dioxide, and the

Elizabeth Kolbert wrote last month about the idea that human impacts on the planet will long outlive us. David Liittschwager's photos of life in one cubic foot of soil or sea appeared in February 2010.

THE UNMAKING OF SHELLS AND SKELETONS

Snails, barnacles, sea urchins, corals—there's a long list of marine organisms that make their hard parts by combining calcium and carbonate ions they get from the water. When atmospheric carbon dioxide levels go up, the organisms' supply of essential carbonate goes down. Here's how.

- 1 Increasing CO₂ in the air forces more CO₂ into surface waters. Slowly, it spreads into the deep.
- 2 CO₂ reacts with water, releasing hydrogen ions, which acidify the water. (They lower its pH.)
- 3 Hydrogen ties up carbonate ions, converting them into bicarbonate ions.



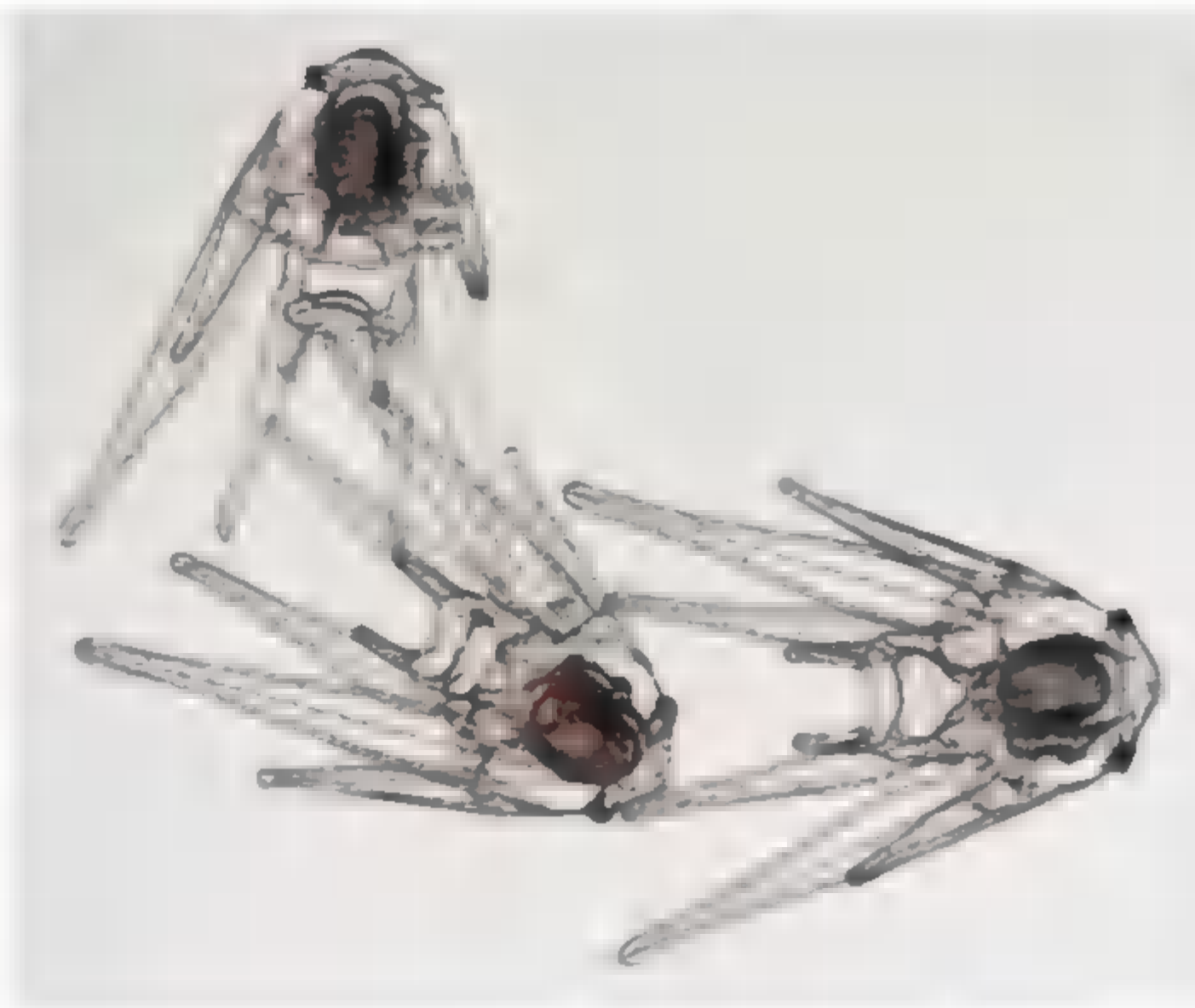
A GROWING PROBLEM FOR CORAL REEFS

In the late 1800s, when fossil-fuel carbon dioxide began to pile up rapidly in the atmosphere and acidify the ocean, tropical corals weren't yet affected. But today carbonate levels have dropped substantially near the Poles; by 2100 they may be too low even in the tropics for reefs to survive.





The sea star on the left was raised in normal water in Kiel, Germany; the one on the right, initially identical, was raised in conditions that could occur in the Baltic Sea by 2100. Ocean acidification is amplified in some coastal waters by pollution from the land, which fertilizes blooms of microbes that take oxygen out of the water and put in more CO₂. The photographs are to scale. The sea star on the right weighs only a fifth as much as its peer.



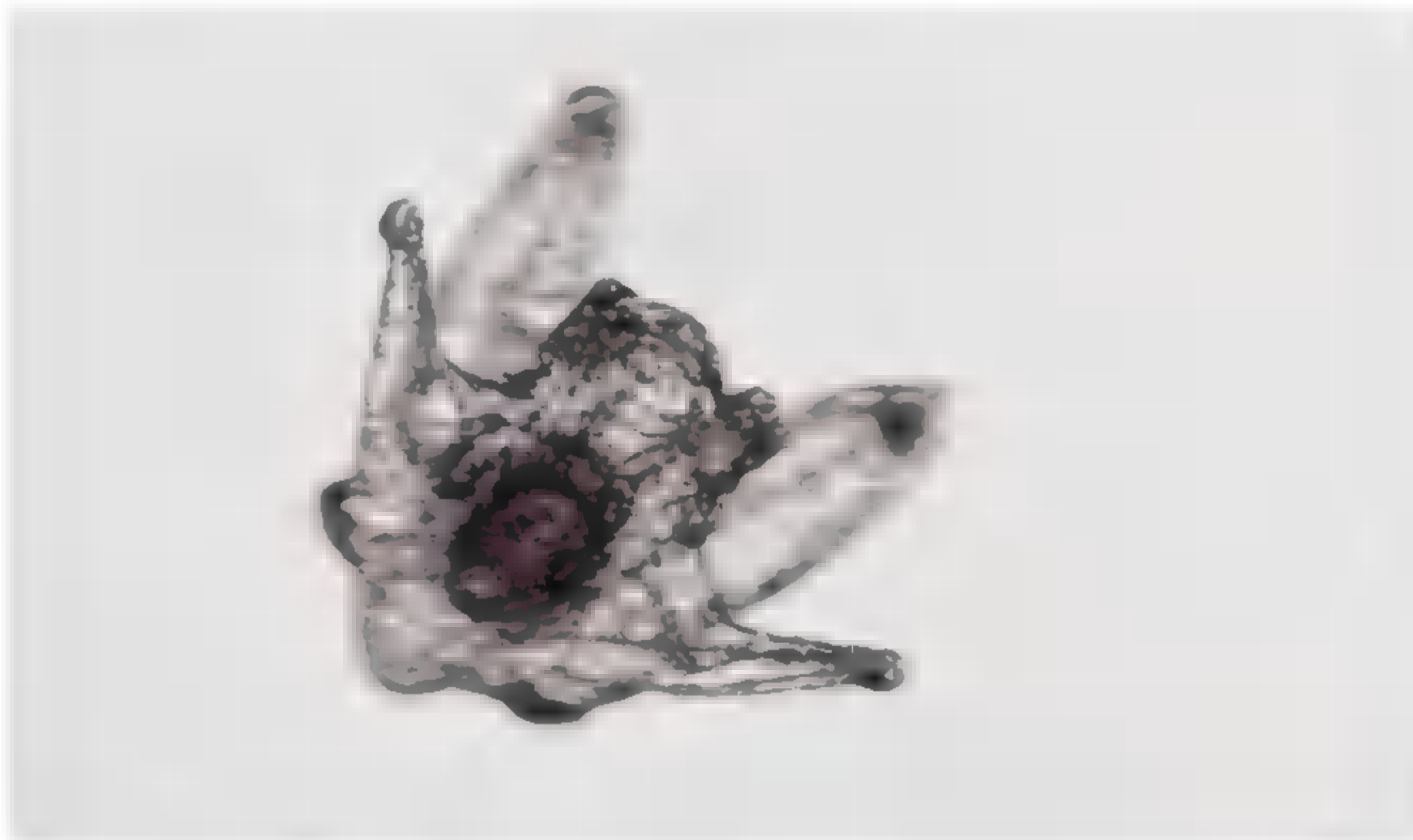
world now emits more than 30 billion tons of CO₂ each year. Meanwhile, natural processes that could counter acidification—such as the weathering of rocks on land—operate far too slowly to make a difference on a human time-scale. Even if CO₂ emissions were somehow to cease today, it would take tens of thousands of years for ocean chemistry to return to its pre-industrial condition.

Acidification has myriad effects. By favoring some marine microbes over others, it is likely to alter the availability of key nutrients like iron and nitrogen. For similar reasons it may let more sunlight penetrate the sea surface. By changing the basic chemistry of seawater, acidification is also expected to reduce the water's ability to absorb and muffle low-frequency sound by up to 40 percent, making some parts of the ocean noisier. Finally, acidification interferes with reproduction in some species and with the ability of others—the so-called calcifiers—to form shells and stony skeletons of calcium carbonate. These last effects are the best documented ones, but whether they will prove the most significant in the long run is unclear.

In 2008 a group of more than 150 leading researchers issued a declaration stating that they were “deeply concerned by recent, rapid changes in ocean chemistry,” which could within decades “severely affect marine organisms, food webs, biodiversity, and fisheries.” Warm-water coral reefs are the prime worry. But because carbon dioxide dissolves more readily in cold water, the impact may actually show up first closer to the Poles. Scientists have already documented significant effects on pteropods—tiny swimming snails that are an important food for fish, whales, and birds in both the Arctic and the Antarctic. Experiments show that pteropod shells grow more slowly in acidified seawater.

Will organisms be able to adapt to the new ocean chemistry? The evidence from Castello Aragonese is not encouraging. The volcanic vents have been pouring CO₂ into the water for at least a thousand years, Hall-Spencer told me when I visited. But the area where the pH is 7.8—the level that may be reached oceanwide by the end of the century—is missing nearly a third of the species that live nearby, outside the vent system. Those species have had “generations on

A female sea urchin remains poised atop a flask (far left) that has just collected her yellow mass of eggs. Three weeks later the healthy larvae (left) look like crystal spaceships, with long rods of calcium carbonate that form the larval skeleton. In contrast, urchin larvae raised in acidified water are stunted (like the one below) and more vulnerable to predators.



generations to adapt to these conditions,” Hall-Spencer said, “yet they’re not there.

“Because it’s so important, we humans put a lot of energy into making sure that the pH of our blood is constant,” he went on. “But some of these lower organisms, they don’t have the physiology to do that. They’ve just got to tolerate what’s happening outside. And so they get pushed beyond their limits.”

FIFTY MILES OFF THE COAST of Australia and half a world away from Castello Aragonese lies the equally tiny One Tree Island. One Tree, which actually has several hundred trees, is shaped like a boomerang, with two arms that stretch out into the Coral Sea. In the crook of the boomerang there’s a small research station run by the University of Sydney. As it happened, just as I arrived one spectacular summer afternoon, an enormous loggerhead turtle heaved herself up onto the beach in front of the lab buildings. The island’s entire human population—11 people, not including me—gathered around to watch.

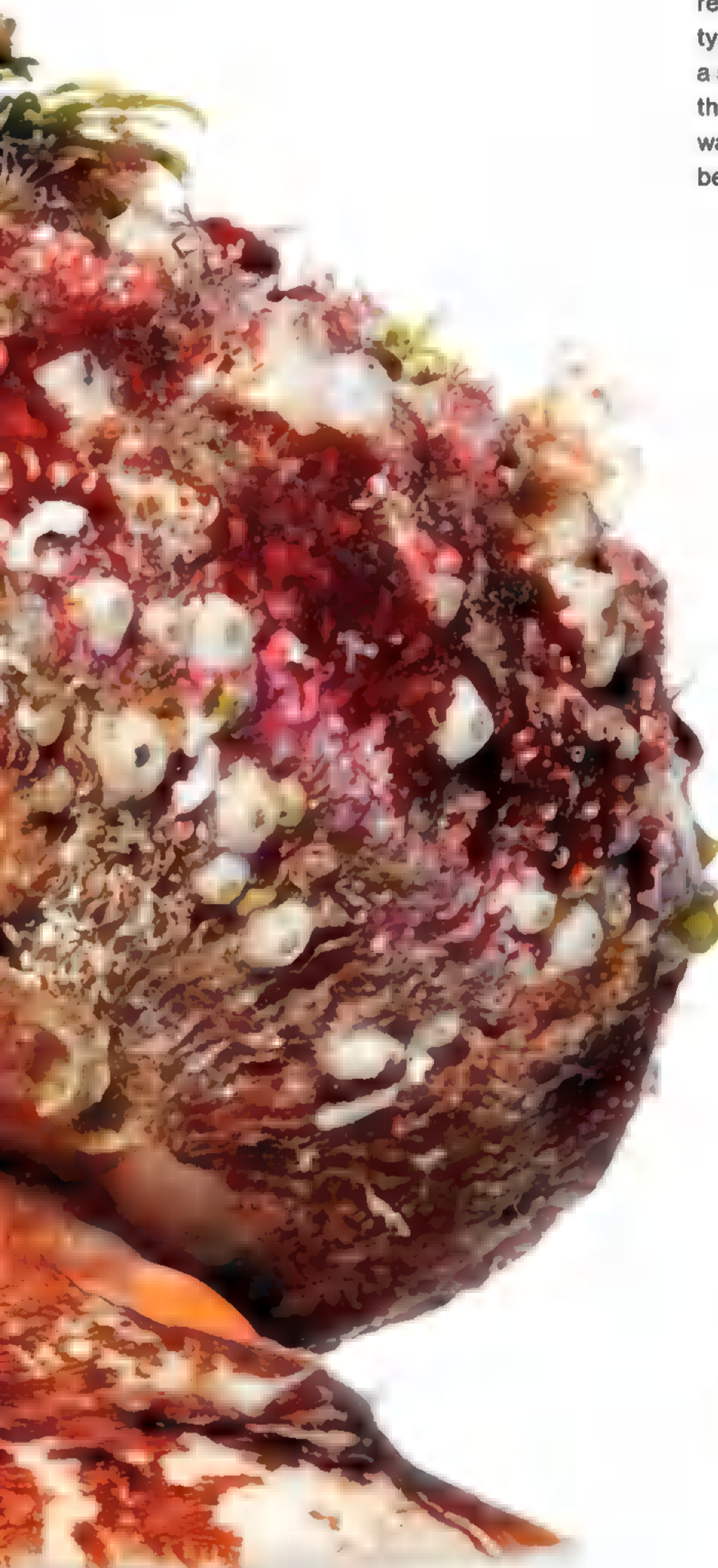
One Tree Island is part of the Great Barrier Reef, the world’s largest reef complex, which

stretches for more than 1,400 miles. The entire island is composed of bits of coral rubble, ranging from marble to basketball size, that began piling up after a peculiarly violent storm about 4,000 years ago. Even today, the island has nothing that could really be called dirt. The trees seem to rise up directly out of the rubble like flagpoles.

When scientists first started visiting the island in the 1960s, they posed questions like, How do reefs grow? Nowadays the questions are more urgent. “Something like 25 percent of all species in the oceans spend at least part of their life in coral reef systems,” Ken Caldeira, an expert on ocean acidification at the Carnegie Institution, said one evening before heading out to collect water samples on the reef. “Corals build the architecture of the ecosystem, and it’s pretty clear if they go, the whole ecosystem goes.”

Coral reefs are already threatened by a wide array of forces. Rising water temperatures are producing more frequent “bleaching” events, when corals turn a stark white and often die. Overfishing removes grazers that keep reefs from being overgrown with algae. Agricultural runoff fertilizes algae, further upsetting





At left, barnacles and tube worms vie for space with red and green algae and orange bryozoans on a typical snail shell near Castello Aragonese. Below, a snail found near the CO₂ vents there isn't stunted—the photos aren't to the same scale. But the acidified water has denuded it, and its shell's outer layer has been corroded at the center, leaving a pearly sheen.





Cuttlefish actually grow well in acidified water; the platelike shell in the animal's back gets denser (far right) than it does at current CO₂ levels (right). That might make swimming harder, though—the gas-filled shell provides buoyancy.

reef ecology. In the Caribbean some formerly abundant coral species have been devastated by an infection that leaves behind a white band of dead tissue. Probably owing to all these factors, coral cover in the Caribbean declined by around 80 percent between 1977 and 2001.

Ocean acidification adds yet another threat, one that may be less immediate but ultimately more devastating to hard, reef-building corals. It undermines their basic, ancient structure—the stony skeleton that's secreted by millions upon millions of coral polyps over thousands of years.

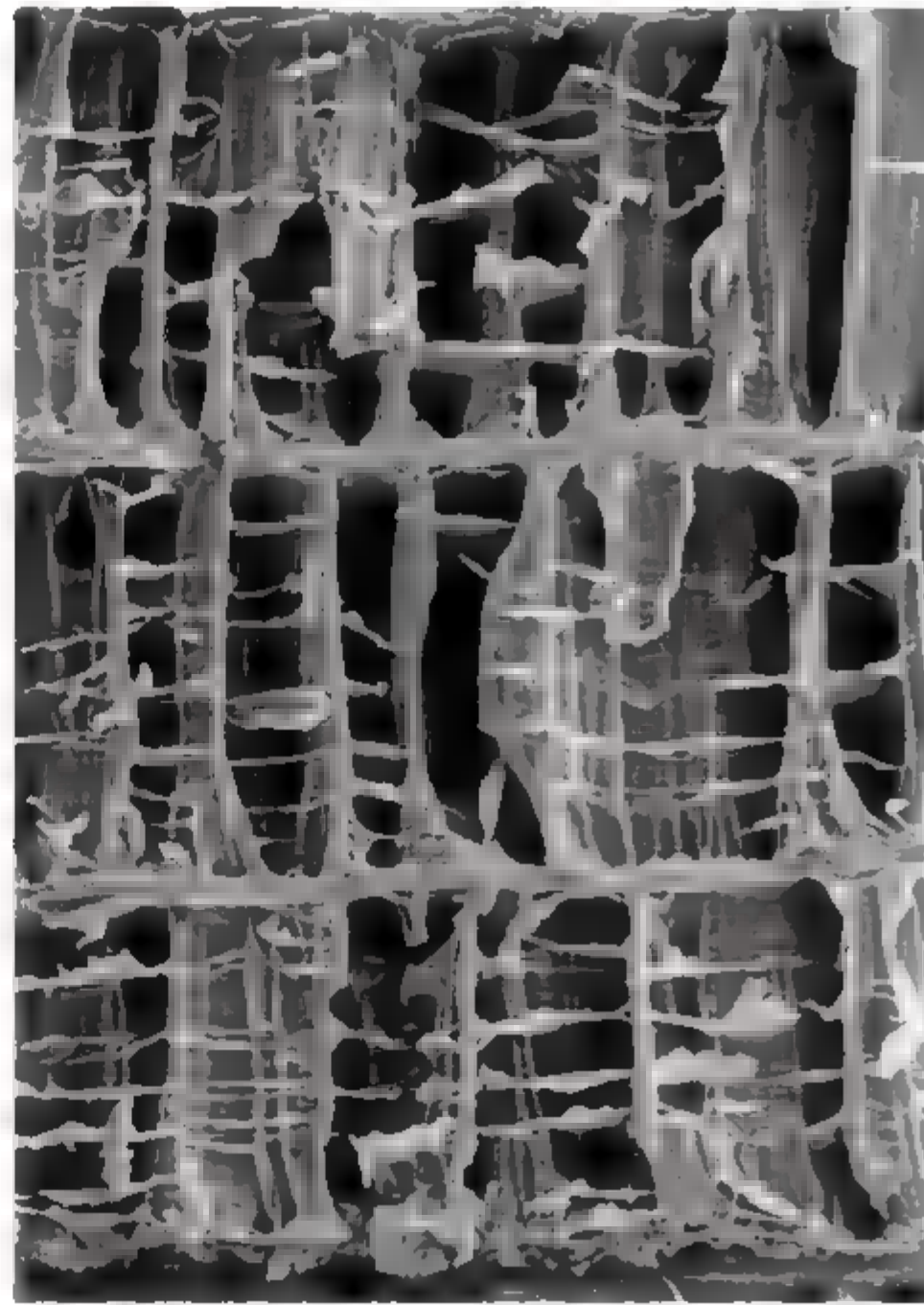
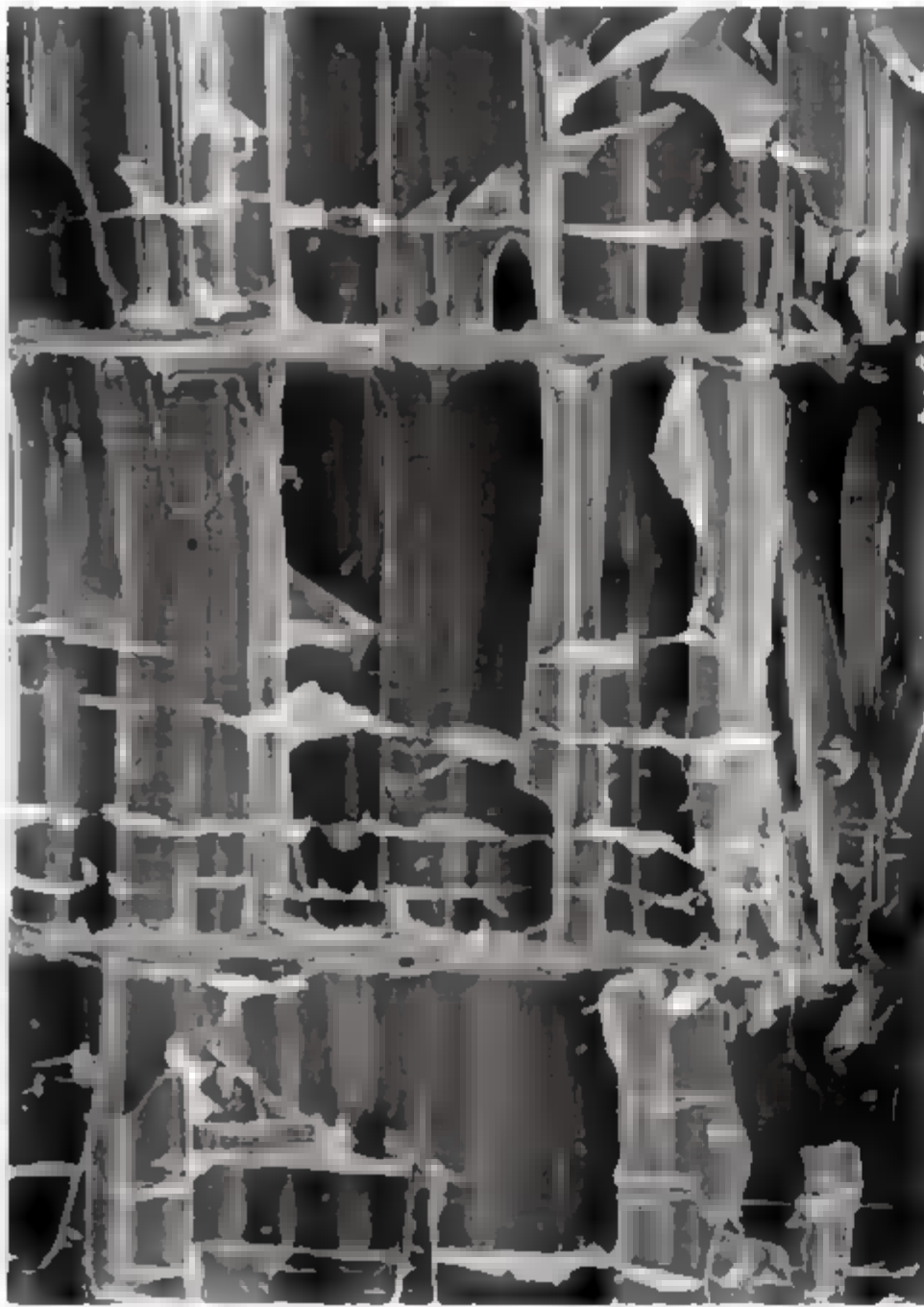
Coral polyps are tiny animals that form a thin layer of living tissue on the surface of a reef. They're shaped a bit like flowers, with six or more tentacles that capture food and feed it to a central mouth. (Many corals actually get most of their food from algae that live and photosynthesize inside them; when corals bleach, it's because stress has prompted the polyps to expel those dark symbionts.) Each polyp surrounds itself with a protective, cup-shaped exoskeleton of calcium carbonate that contributes to the collective skeleton of the whole colony.

To make calcium carbonate, corals need two

ingredients: calcium ions and carbonate ions. Acids react with carbonate ions, in effect tying them up. So as atmospheric CO₂ levels rise, carbonate ions become scarcer in the water, and corals have to expend more energy to collect them. Under lab conditions coral skeleton growth has been shown to decline pretty much linearly as the carbonate concentration drops off.

Slow growth may not matter much in the lab. Out in the ocean, though, reefs are constantly being picked at by other organisms, both large and small. (When I went snorkeling off One Tree Island, I could hear parrotfish chomping away at the reef.) "A reef is like a city," said Ove Hoegh-Guldberg, who used to direct the One Tree Island Research Station and now heads the Global Change Institute at Australia's University of Queensland. "You've got construction firms and you've got demolition firms. By restricting the building materials that go to the construction firms, you tip the balance toward destruction, which is going on all the time, even on a healthy reef. In the end you wind up with a city that destroys itself."

By comparing measurements made in the



1970s with those taken more recently, Caldeira's team found that at one location on the northern tip of the reef, calcification had declined by 40 percent. (The team was at One Tree to repeat this study at the southern tip of the reef.) A different team using a different method has found that the growth of *Porites* corals, which form massive, boulderlike clumps, declined 14 percent on the Great Barrier Reef between 1990 and 2005.

OCEAN ACIDIFICATION seems to affect corals' ability to produce new colonies as well. Corals can, in effect, clone themselves, and an entire colony is likely to be made up of genetically identical polyps. But once a year, in summer, many species of coral also engage in "mass spawning," a kind of synchronized group sex. Each polyp produces a beadlike pink sac that contains both eggs and sperm. On the night of the spawning all the polyps release their sacs into the water. So many sacs are bobbing around that the waves seem to be covered in a veil of mauve.

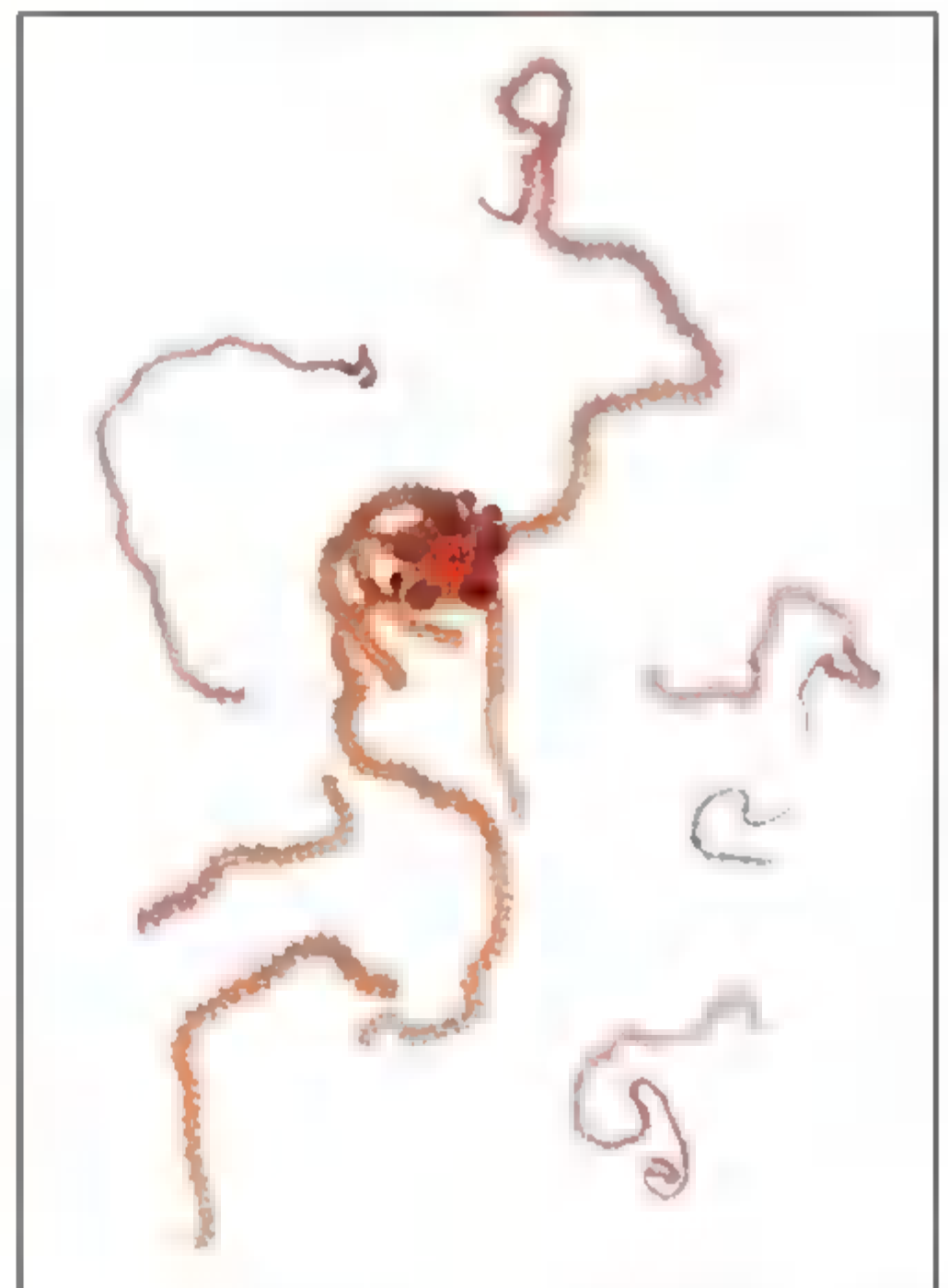
Selina Ward, a researcher at the University of Queensland, has been studying coral reproduction on Heron Island, about ten miles west of

One Tree, for the past 16 years. I met up with her just a few hours before the annual spawning event. She was keeping tabs on a dozen tanks of gravid corals, like an obstetrician making the rounds of a maternity ward. As soon as the corals released their pink sacs, she was planning to scoop them up and subject them to different levels of acidification. Her results so far suggest that lower pH leads to declines in fertilization, in larval development, and also in settlement—the stage at which the coral larvae drop out of the water column, attach themselves to something solid, and start producing new colonies. "And if any of those steps doesn't work, you're not going to get replacement corals coming into your system," Ward said.

The reefs that corals maintain are crucial to an incredible diversity of organisms. Somewhere between one and nine million marine species live on or around coral reefs. These include not just the fancifully colored fish and enormous turtles that people visit reefs to see, but also sea squirts and shrimps, anemones and clams, sea cucumbers and worms—the list goes on and on. The nooks and crevices on a reef provide



A brittle star in the lab can handle water acidified by high CO₂. It can handle water spiked with triclosan, an antimicrobial found in soaps and skin creams—more and more of which is reaching the oceans through sewage discharges. But when a brittle star is hit with high CO₂ and triclosan at once—mimicking the “stress cocktail” of the future—it sheds its arms (below).



homes for many species, which in turn provide resources for many others.

Once a reef can no longer grow fast enough to keep up with erosion, this community will crumble. “Coral reefs will lose their ecological functionality,” Jack Silverman, a member of Caldeira’s team at One Tree, told me. “They won’t be able to maintain their framework. And if you don’t have a building, where are the tenants going to live?” That moment could come by 2050. Under the business-as-usual emissions scenario, CO₂ concentrations in the atmosphere will be roughly double what they were in preindustrial times. Many experiments suggest that coral reefs will then start to disintegrate.

“Under business as usual, by mid-century things are looking rather grim,” Caldeira said. He paused for a moment. “I mean, they’re looking grim already.”

CORALS, OF COURSE, are just one kind of calcifier. There are thousands of others. Crustaceans like barnacles are calcifiers, and so are echinoderms like sea stars and sea urchins and mollusks like clams and oysters. Coralline algae—minute organisms that produce what looks like a coating of pink or lilac paint—are also calcifiers. Their calcium carbonate secretions help cement coral reefs together, but they’re also found elsewhere—on sea grass at Castello Aragonese, for instance. It was their absence from the grass near the volcanic vents that made it look so green.

The seas are filled with one-celled calcifying plants called coccolithophores, whose seasonal blooms turn thousands of square miles of ocean a milky hue. Many species of planktonic foraminifera—also one-celled—are calcifiers; their dead shells drift down to the ocean floor in what’s been described as a never ending rain. Calcifiers are so plentiful they’ve changed the Earth’s geology. England’s White Cliffs of Dover, for example, are the remains of countless ancient calcifiers that piled up during the Cretaceous period.

Acidification makes all calcifiers work harder, though some seem better able to cope. In experiments on 18 species belonging to different taxonomic groups, researchers at the Woods Hole

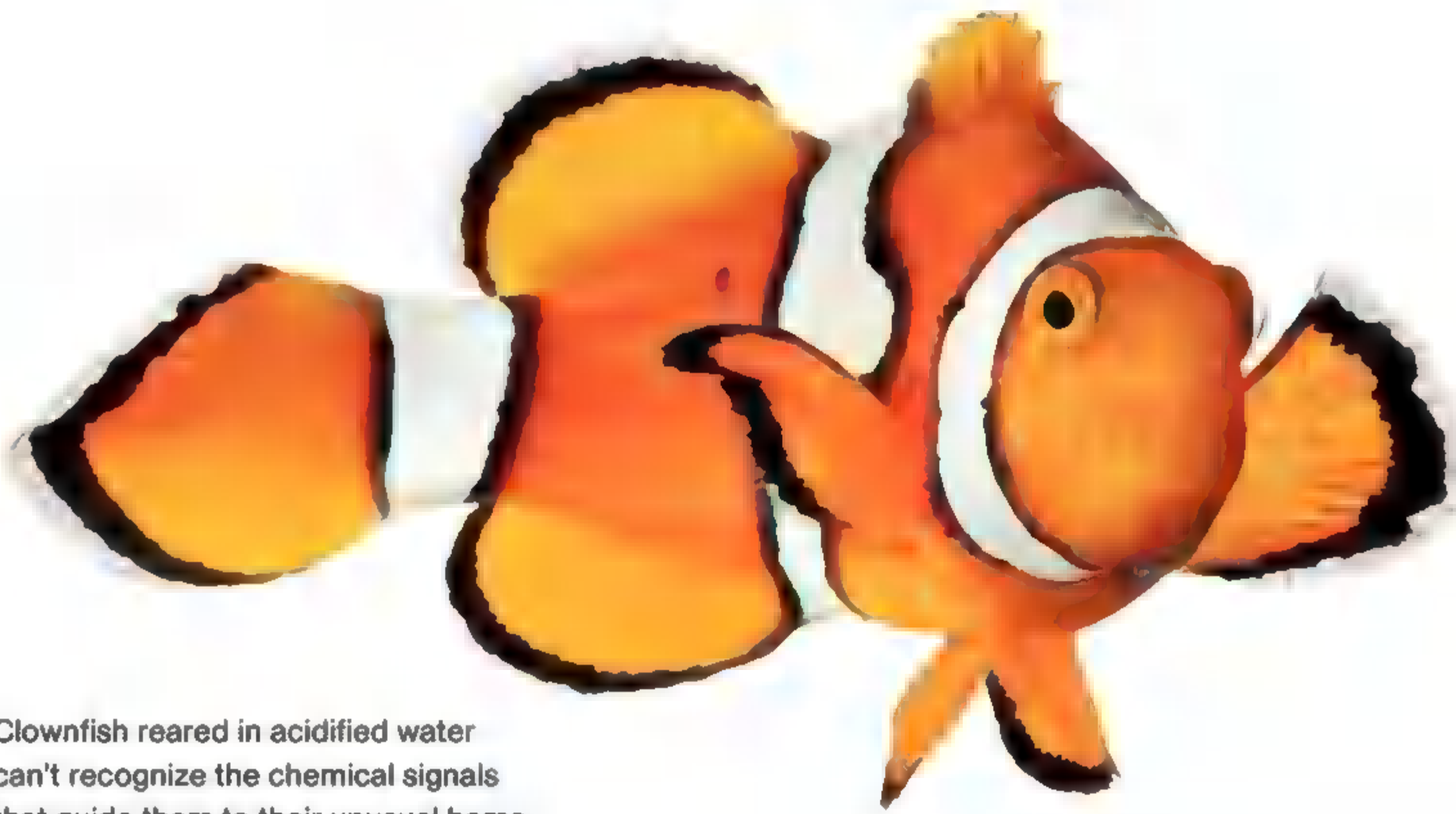
Oceanographic Institution found that while a majority calcified less when CO₂ was high, some calcified more. One species—blue mussels—showed no change, no matter how acidified the water.

“Organisms make choices,” explained Ulf Riebesell, a biological oceanographer at the Leibniz Institute of Marine Sciences in Kiel, Germany. “They sense the change in their environment, and some of them have the ability to compensate. They just have to invest more energy into calcification. They choose, ‘OK, I’ll invest less in reproduction’ or ‘I’ll invest less in growth.’” What drives such choices, and whether they’re viable over the long term, is not known; most studies so far have been performed on creatures living for a brief time in tanks, without other species that might compete with them. “If I invest less in growth or in reproduction,” Riebesell went on, “does it mean that somebody else who does not have to make this choice, because they are not calcifying, will win out and take my spot?”

Meanwhile, scientists are just beginning to explore the way that ocean acidification will affect more-complex organisms such as fish and marine mammals. Changes at the bottom of the marine food web—to shell-forming pteropods, say, or coccolithophores—will inevitably affect the animals higher up. But altering oceanic pH is also likely to have a direct impact on their physiology. Researchers in Australia have found, for example, that young clownfish—the real-life versions of Nemo—can’t find their way to suitable habitat when CO₂ is elevated. Apparently the acidified water impairs their sense of smell.

DURING THE LONG HISTORY of life on Earth, atmospheric carbon dioxide levels have often been higher than they are today. But only very rarely—if ever—have they risen as quickly as right now. For life in the oceans, it’s probably the rate of change that matters.

To find a period analogous to the present, you have to go back at least 55 million years, to what’s known as the Paleocene-Eocene Thermal Maximum or PETM. During the PETM huge quantities of carbon were released into the atmosphere,



Clownfish reared in acidified water can't recognize the chemical signals that guide them to their unusual home—the tentacles of an anemone. Some are even drawn to the scent of predators.

from where, no one is quite sure. Temperatures around the world soared by around ten degrees Fahrenheit, and marine chemistry changed dramatically. The ocean depths became so corrosive that in many places shells stopped piling up on the seafloor and simply dissolved. In sediment cores the period shows up as a layer of red clay sandwiched between two white layers of calcium carbonate. Many deepwater species of foraminifera went extinct.

Surprisingly, though, most organisms that live near the sea surface seem to have come through the PETM just fine. Perhaps marine life is more resilient than the results from places like Castello Aragonese and One Tree Island seem to indicate. Or perhaps the PETM, while extreme, was not as extreme as what's happening today.

The sediment record doesn't reveal how fast the PETM carbon release occurred. But modeling studies suggest it took place over thousands of years—slow enough for the chemical effects to spread through the entire ocean to its depths. Today's rate of emissions seems to be roughly ten times as fast, and there's not enough time for the water layers to mix. In the coming

century acidification will be concentrated near the surface, where most marine calcifiers and all tropical corals reside. "What we're doing now is quite geologically special," says climate scientist Andy Ridgwell of the University of Bristol, who has modeled the PETM ocean.

Just how special is up to us. It's still possible to avert the most extreme acidification scenarios. But the only way to do this, or at least the only way anyone has come up with so far, is to dramatically reduce CO₂ emissions. At the moment, corals and pteropods are lined up against a global economy built on cheap fossil fuels. It's not a fair fight. □



SEVEN BILLION IN MAY

How Bangladesh is facing the challenges of a growing population and rising seas.

The Pulitzer Center on Crisis Reporting and PBS NewsHour join us in reporting on population issues throughout the year.

The magazine thanks the David and Lucile Packard Foundation, the Wallace Global Fund, and National Geographic Society members for their generous support of this series of articles.

An abandoned rail line has become an elevated park known as the High Line. Dense plantings at the southern end heighten the contrast with the old steel structure as well as with the cityscape. The Standard Hotel, one of three buildings that cross over the High Line, is on the right.



MIRACLE

ABOVE

MANHATTAN



BY PAUL GOLDBERGER

PHOTOGRAPHS BY DIANE COOK AND LEN JENSHEL

P

arks in large cities are usually thought of as refuges, as islands of green amid seas of concrete and steel. When you approach the High Line in the Chelsea neighborhood on the lower west side of Manhattan, what you see first is the kind of thing urban parks were created to get away from—

a harsh, heavy, black steel structure supporting an elevated rail line that once brought freight cars right into factories and warehouses and that looks, at least from a distance, more like an abandoned relic than an urban oasis.

Until recently the High Line was, in fact, an urban relic, and a crumbling one at that. Many of its neighbors, as well as New York's mayor for much of the 1990s, Rudolph Giuliani, couldn't wait to tear it down. His administration, aware that Chelsea was gentrifying into a neighborhood of galleries, restaurants, and loft living, felt the surviving portion of the High Line, which winds its way roughly a mile and a half from Gansevoort Street to 34th Street (a section farther south was torn down years ago), was an ugly deadweight. They were certain this remnant of a different kind of city had to be removed for the neighborhood to realize its full potential.

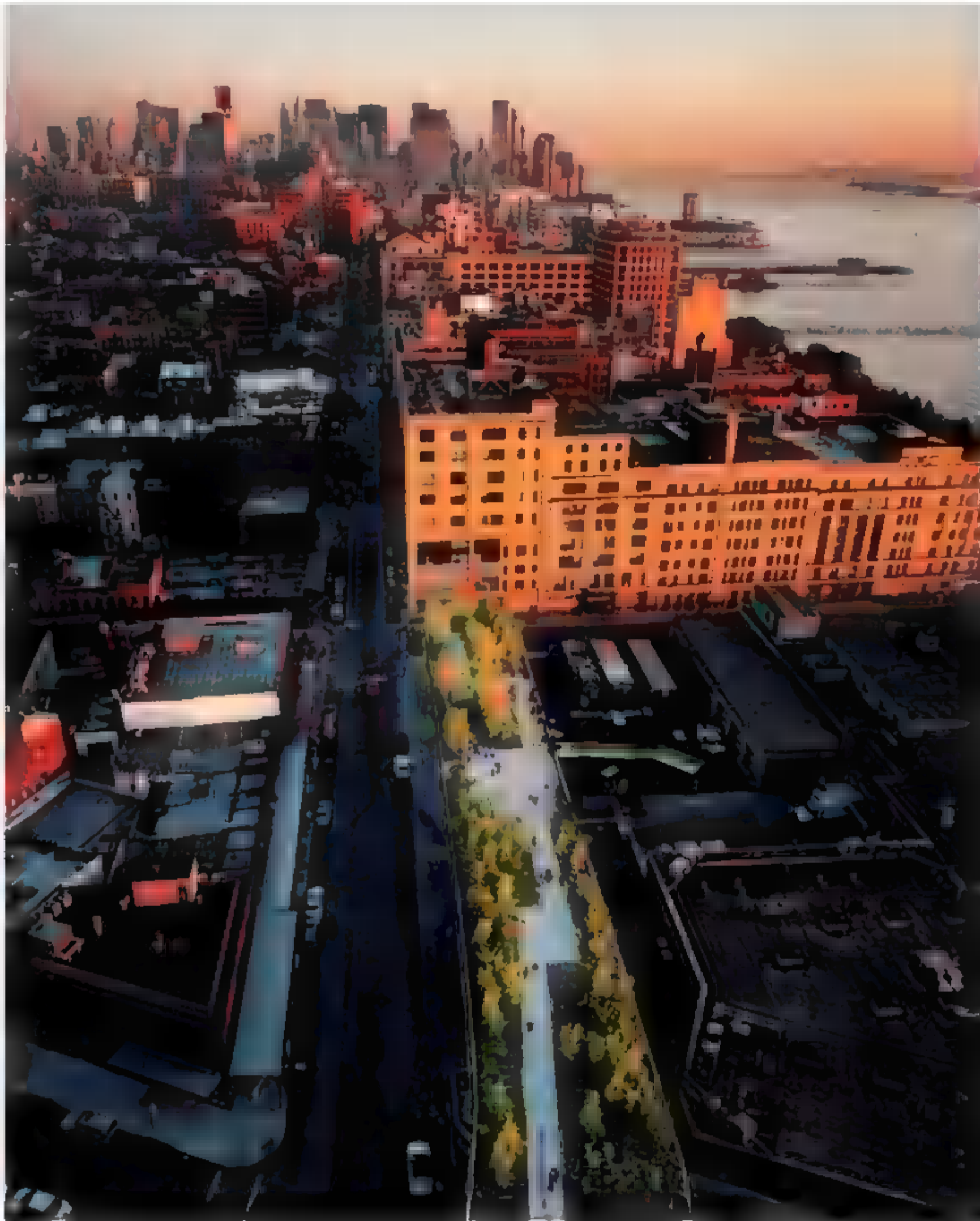
Never have public officials been so wrong. Almost a decade after the Giuliani administration tried to tear the High Line down, it has been turned into one of the most innovative and inviting public spaces in New York City and perhaps the entire country. The black steel columns that once supported abandoned train tracks now hold up an elevated park—part promenade, part town square, part botanical garden. The southern third,

which begins at Gansevoort Street and extends to West 20th Street, crossing Tenth Avenue along the way, opened in the summer of 2009. This spring a second section will open, extending the park ten more blocks, roughly a half mile, to 30th Street. Eventually, supporters hope, the park will cover the rest of the High Line (map, pages 128-29).

Walking on the High Line is unlike any other experience in New York. You float about 25 feet above the ground, at once connected to street life and far away from it. You can sit surrounded by carefully tended plantings and take in the sun and the Hudson River views, or you can walk the line as it slices between old buildings and past striking new ones. I have walked the High Line dozens of times, and its vantage point, different from that of any street, sidewalk, or park, never ceases to surprise and delight. Not the least of the remarkable things about the High Line is the way, without streets to cross or traffic lights to wait for, ten blocks pass as quickly as two.

NEW YORK IS A CITY in which good things rarely happen easily and where good designs are often compromised, if they are built at all. The High Line is a happy exception, that rare New York situation in which a wonderful idea was not only realized but turned out better than anyone had imagined. It isn't often in any city, let alone New York, that an unusually sophisticated concept for a public place makes its way through the design process, the political process, and the construction process largely intact. The designers were

Paul Goldberger, architecture critic for the New Yorker, is the author of Why Architecture Matters. Diane Cook and Len Jenshel photographed Mount St. Helens for the May 2010 issue.



The High Line once stretched farther into lower Manhattan, often passing right through factories. That southernmost section was torn down in the 1960s, long before any thought of turning the line into a park.

landscape architect James Corner of Field Operations and the architecture firm of Diller Scofidio + Renfro, who joined forces to produce the winning scheme in a competition that pitted them against such notables as Zaha Hadid, Steven Holl, and landscape architect Michael Van Valkenburgh.

Their plan struck a balance between refinement and the rough-hewn, industrial quality of the High Line. “We envisioned it as one long, meandering ribbon but with special episodes,” Corner told me. “We wanted to keep the feeling of the High Line consistent but at the same time have some variations.” The design included

sleek wooden benches that appear to peel up from the park surface, but also kept many of the original train tracks, setting them into portions of the pavement and landscape. Working with Dutch landscape architect Piet Oudolf, Corner recommended a wide range of plantings, with heavy leanings toward tall grasses and reeds that recalled the wildflowers and weeds that had sprung up during the High Line’s long abandonment. (The line, which opened in 1934, was little used after the 1960s, although its final train, carrying frozen turkeys, didn’t travel down the track until 1980.)



the sooner you park your car,
the sooner you can stop thinking



A kiss is perhaps the only reason to miss the view over Tenth Avenue that the architects made one of the High Line park's main focal points. Their design turned what could have been an ordinary bridge into a striking urban amphitheater, with wooden bleachers stepping down to a window right above the traffic.

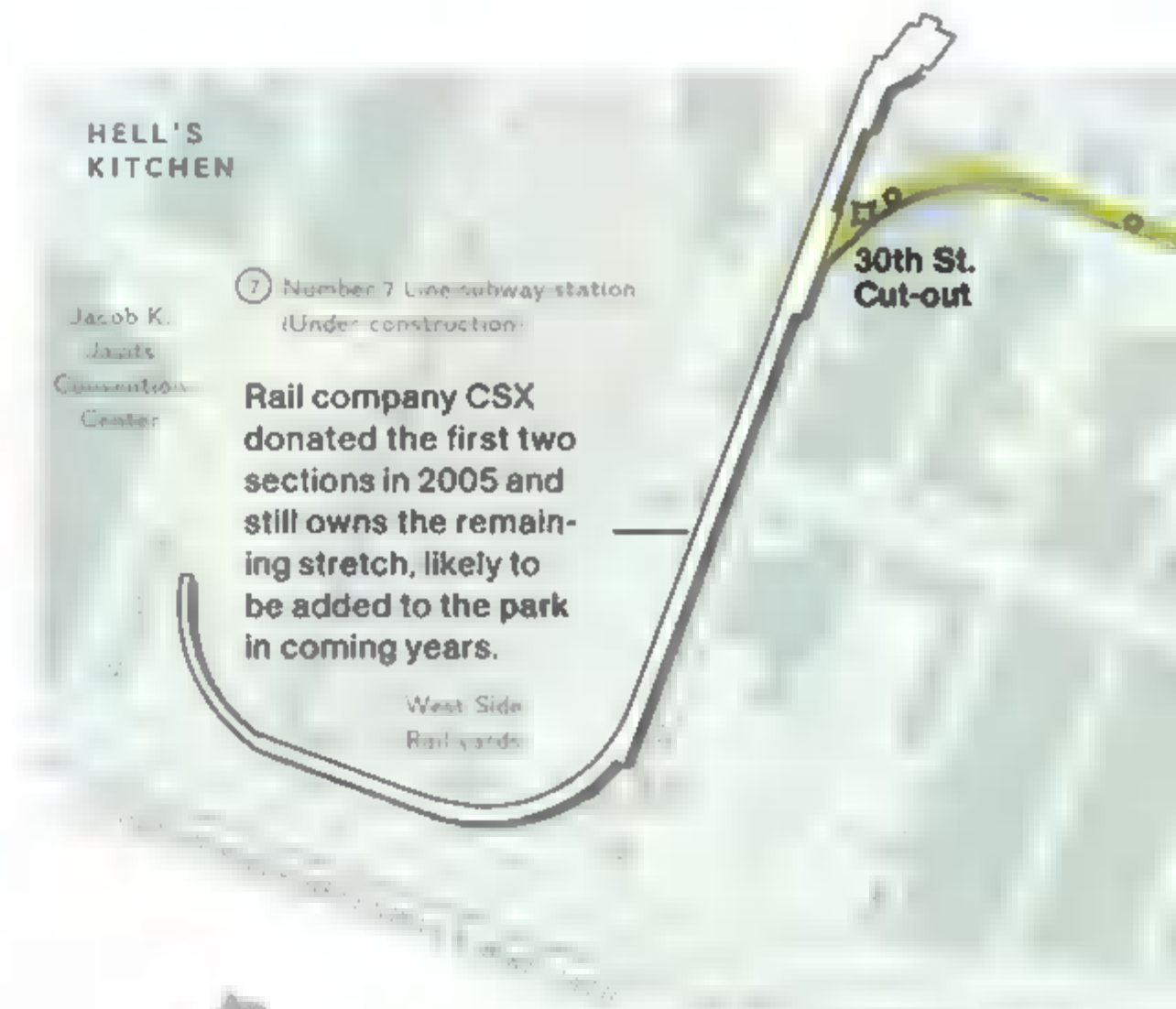
Naomi Goldberg Haas's dance company performed *Autumn Crossing* last fall in the Chelsea Market Passage, a covered portion of the High Line designated for public art and special events.



Early in the two and a half decades that the High Line was unused and untouched, an obsessive rail buff named Peter Obletz purchased the elevated structure for ten dollars from Conrail with the intention of restoring it to rail use. Obletz's ownership was held up in a five-year legal battle, which he lost. He died in 1996 but is, in a sense, a spiritual parent of the High Line preservation effort. So is photographer Joel Sternfeld. During the derelict years he made striking images of the High Line as a ribbon of green snaking through an industrial cityscape. Widely reproduced, his photographs played a significant role in building a constituency for saving the line for public use. Sternfeld showed that this clunky industrial object really could look like a park.

But the real heroes of the story are two men who met for the first time at a community meeting on the future of the line in 1999. Joshua David was then 36, a freelance writer who lived on West 21st Street, not far from the midsection of the High Line. Robert Hammond, an artist who worked for start-up tech companies to earn a living, was 29 and lived in Greenwich Village a few blocks from the southern terminus.

"I saw an article in the *New York Times* saying that the High Line was going to be demolished, and I wondered if anyone was going to try to save it," Hammond said to me. "I was in love with the steel structure, the rivets, the ruin. I assumed that



THE HIGH LINE

- **Section one**
0.5 mile, June 2009
- **Section two**
0.5 mile, opening spring 2011
- Section three**
0.5 mile, development pending
- Point of Interest**
- **Access point**

some civic group was going to try and preserve it, and I saw that it was on the agenda for a community board meeting. I went to see what was going on, and Josh was sitting next to me. We were the only people at the meeting who were interested in saving it."

"The railroad sent representatives who showed some plans to reuse it, which enraged the people who were trying to get it torn down," David explained. "That's what sparked the conversation between me and Robert—we couldn't believe the degree of rage some of those people had."

David and Hammond asked railroad officials to take them to look at the High Line. "There's a legend that we snuck in, but it's not true," Hammond said. "When we got up there, we saw a mile and a half of wildflowers in the middle of Manhattan."

"New Yorkers always dream of finding open space—it's a fantasy when you live in a studio apartment," David said.

Amazed by the expansiveness of the space, the



two men were determined to keep the High Line from being torn down. In the fall of 1999 they formed Friends of the High Line. At first their ambitions were modest. “We just wanted to fight Giuliani to keep it from being demolished,” Hammond said. “But preservation was only the first step, and we began to realize that we could create a new public place.”

The organization crept forward slowly. Then came the attack on the World Trade Center in 2001. “We thought no one would care about the High Line at that point,” Hammond said, “but the increased interest in urban planning and design with the ground zero design process paved the way for heightened interest in our project. People felt this was one positive thing they could do.” In 2002 Friends of the High Line commissioned an economic feasibility study, which concluded that, contrary to the Giuliani administration’s claim, turning the High Line into a park would help the neighborhood, not slow its development.

Not long before, an abandoned rail line in eastern Paris, near the Place de la Bastille, had been turned into a highly successful linear park called the Promenade Plantée, which gave the group’s idea for the High Line a serious precedent. Although Parisian models don’t transfer easily into New York, the existence of the Promenade Plantée did a lot to increase the credibility of David and Hammond’s crusade. They began to think their idea of turning the High Line into a new kind of public place might be achievable.

Friends of the High Line may have been a grassroots group, but its roots were planted firmly in the world’s most sophisticated art and design community. In 2003 the pair decided to hold an “ideas competition”—not a formal architectural contest but an invitation to anyone to submit an idea and a design for what the High Line might become. They expected a few dozen proposals from New Yorkers. Their call brought 720 entries from 36 countries.

Workers installed trees in the second section of the High Line last summer so plantings could take root and flourish before the spring opening of the next phase of the park, a half-mile stretch extending from 20th Street to 30th Street.



As New York recovered further from the trauma of September 11, Friends of the High Line continued to grow. It began to attract the attention of younger hedge fund managers and real estate executives with a philanthropic bent, people not established enough to join the boards of the city's major cultural institutions but eager to make a mark. The High Line was tailor-made for them; its annual summer benefit became one of New York's favorite causes and one of the few with a critical mass of supporters under age 40.

It didn't hurt that Michael Bloomberg, who succeeded Giuliani, had a sympathetic view of saving the High Line. Bloomberg, a billionaire who had long been a major donor to the city's cultural institutions, offered support for the High Line plan. The city struck a deal with Friends of the High Line, working with the group to design and construct what would become a new park and offering \$112.2 million toward the projected \$153-million cost of the first two phases, with another \$21.4 million from federal and state funds. Friends of the High Line agreed to come up with \$19.4 million and pay the majority of operating costs once the park was open.

In 2005 City Planning Commissioner Amanda Burden crafted zoning provisions for the area, setting rules for new construction that was cropping up. By the time the zoning was in place, the surrounding area had become one of the city's hottest neighborhoods. Buildings by celebrated architects were in the works, including the IAC headquarters designed by Frank Gehry. In spring of 2006 the first piece of rail track was lifted off the High Line, the equivalent of a groundbreaking ceremony, and construction began.

FROM THE DAY the first section of the High Line opened in June 2009, it has been one of the city's major tourist attractions, and you are as likely to hear visitors speaking German or Japanese as English. Yet it is just as much a neighborhood park. When I joined Hammond for a walk along the High Line on a sunny day last fall, a section the designers had designated as a kind of sun-deck was jammed, and there seemed to be as many locals treating the area as the equivalent of

their own beach as visitors out for a promenade.

The sundeck area is one of the places James Corner likes to refer to as "episodes" along the High Line. There are more in the first section, because the route bends and turns, slips under three different buildings to become briefly tunnel-like, then opens up to offer vistas of the midtown skyline or the Hudson River. At the point at which the High Line crosses Tenth Avenue, it morphs once again, this time into an amphitheater-like space suspended over the avenue, allowing you to sit and watch the traffic glide beneath you.

The route of the elevated line straightens out in the second section, north of 20th Street, presenting the designers with a different kind of challenge. "It's all wide open with views of the city, and then all of a sudden you're walking between two building walls," Corner said. "It's dead straight, and we had to make it so you didn't feel you were in a corridor." He decided to start off the second section with a dense thicket of plantings, much heavier than anything in the first section, on the theory that if he couldn't make the tightness go away, he should accentuate its drama for a block or so, then quickly downshift to a relaxed, open lawn. After that comes what the designers call the flyover: a metal structure that lifts the walkway up and allows a dense landscape of plantings to grow beneath. North of that is another seating area, this one looking down onto the street through an enormous white frame that alludes to the billboards that once adorned the neighboring buildings. Just beyond, a long stretch of promenade is lined with wildflowers.

On the day I toured the new section with Robert Hammond, much of the planting was already in place. Even though construction was still going on, it was strangely quiet. We walked the length of the new section; Hammond said the quiet reminded him of the way the High Line was at the very beginning, before the crowds started to pour in. "I thought I would miss the way it was," he said. But the High Line's overwhelming success, he has realized, has given him a satisfaction far beyond the pleasures of seeing the old steel structure empty. □

Some portions of the High Line encourage an urban stroll, but the Chelsea Market Passage, at 15th Street, feels more like a balcony, positioned to overlook the city and the Hudson River beyond. It is rarely more tranquil than early on a clear evening, as the glowing color of sunset fades from the sky.










The Caledonia, with its walls of glass (opposite page), is one of many apartment houses newly constructed along the High Line. Not long ago, the entire length of the High Line was an unkempt jumble of weeds and wildflowers. The third and last segment (above), to the north of 30th Street, still is.

The unrenovated northern portion of the High Line turns westward, bringing the structure almost to the Hudson River. The rail company CSX still owns the section, but Friends of the High Line hope one day it will be part of the park. If that happens, the Fourth of July view witnessed by a staff member from the group and her companion could be enjoyed by many New Yorkers.







A photograph of a snow frog on a snowy slope. The frog is dark brown and black, positioned on the left side of the frame, facing right. The background is a vast, white, snow-covered slope that extends to the top right corner. A clear blue sky is visible in the upper left corner. The overall scene is bright and high-contrast.

Indomitable Snow Frogs

Cold-blooded frogs can't be coy about romance when fleeting summer comes to the French Alps.

Photographs by Cyril Ruoso



Emerging from a partially frozen pond more than 6,000 feet high in the Alps, European common frogs (*Rana temporaria*) set out to find mates and begin breeding activities. These frogs have adapted to a wide variety of conditions, increasing their range over most of Europe (map). Here on the Massif de Beaufort in the French region of Savoy, water may not thaw until June, leaving

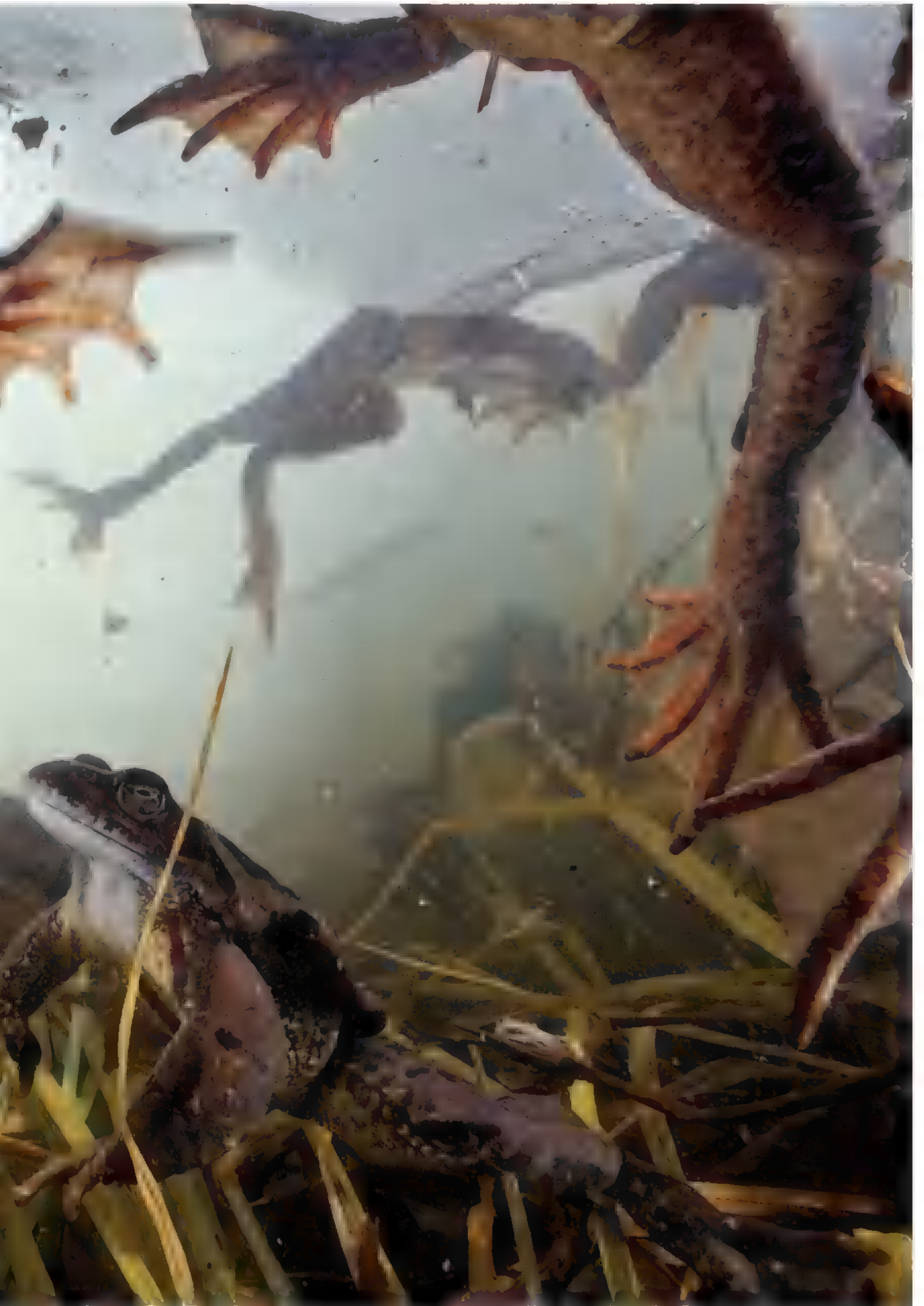


European common frog range
NGM MAPS SOURCE IUCN

only a brief window of warm weather for females to lay eggs and tadpoles to metamorphose into juveniles, known as froglets. Cold-climate frogs grow more slowly than their relatives in temperate areas, but live longer (12 years, compared to 5 for lowland frogs) and so grow larger. They're also active during warmer, daylight hours, unlike their kin elsewhere.



The search for mates often begins underwater, before surface ice has melted. Photographer Cyril Ruoso could hear the calls of male frogs in spring, even through the ice of Alpine ponds.

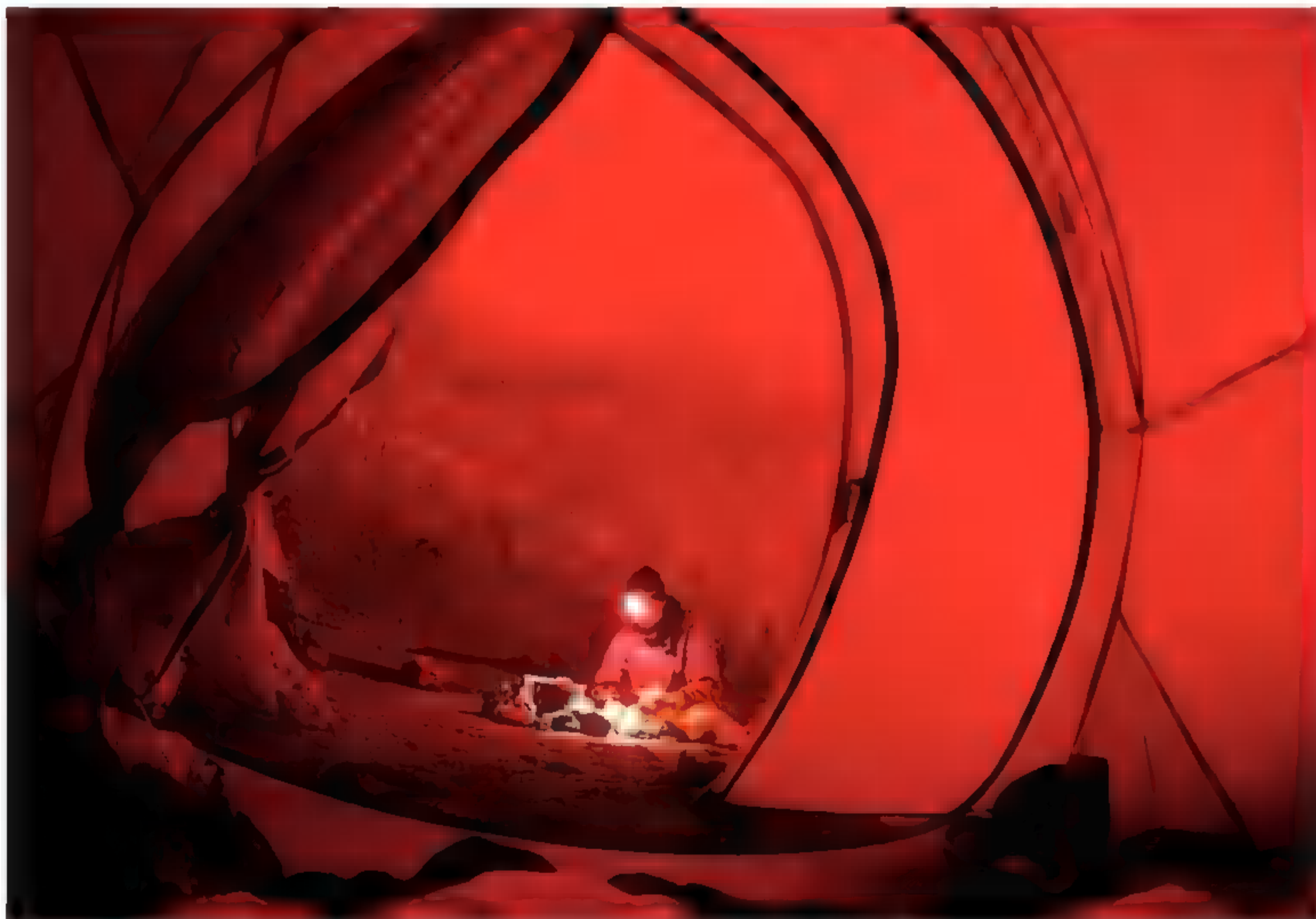




*Cyril Ruoso, author of *The Great Apes*, is with JH Editorial/Minden Pictures. Natural history writer Mel White lives in Little Rock, Arkansas.*



Frogs mate in a position called amplexus, with the smaller male clasping the female from behind in a ride that can last two days or more. As she lays eggs, he expels sperm to fertilize them. Though egg laying takes place in spring, frog pairs in mountain ponds can begin hibernation in amplexus—a months-long embrace that may provide a breeding advantage by allowing mating as quickly as possible once warm weather arrives. Eggs of high-elevation frogs may be 30 percent larger than those of lowland females, giving tadpoles a head start. Eggs and tadpoles of mountain frogs have developed resistance to genetic damage from ultraviolet radiation, a component of sunlight that is more intense in the thinner air of high altitude. —*Mel White*



ON ASSIGNMENT Hot Seat Photographer Carsten Peter is no stranger to extreme conditions. He has chased tornadoes, scuba dived in glaciers, and—for this issue's feature story—rappelled down to the molten inferno inside Nyiragongo volcano in the Democratic Republic of the Congo. For nearly a week Peter and his assistant Chris Heinlein (above) lived out of a tent they'd pitched on the volcano's "second terrace," some 800 feet below the crater's rim. "Everything was embraced by this weird, indirect orange illumination from the boiling lava lake underneath us," remembers Peter. When not battling wind and spurts of acid, the team slept, worked, and made meals by rehydrating freeze-dried food. "It's not haute cuisine down there," he says. The fiery ambience was overwhelmed by a gas-induced smell similar to that of rotten eggs. "Your lungs suffer, but it's a very otherworldly place to stay. I loved it."

Chris Heinlein prepares a simple dinner near his tent inside Nyiragongo volcano.



BOOKS

The 10 Best National Parks

Wondering where to vacation this summer? *The 10 Best of Everything: National Parks* will give you plenty of ideas. Featuring 100 color photographs, this tip-packed guide is the authority on where to find the best hikes, stargazing, campfire spots, lodges, and more in America's outdoor playgrounds (\$21.95).

The Ragged Edge of Silence

Moved by the destruction caused by a 1971 oil spill in San Francisco Bay, John Francis decided he would stop speaking and start walking. In his new book, *The Ragged Edge of Silence*, he shares insights from his 17 years of quiet—and invites readers to try turning down the volume in their own lives (\$26).

If You Have a Superior or Lennox Gas Fireplace

You Could Get a Protective Screen and a Warning Sticker from a Class Action Settlement

There is a Settlement involving Superior and Lennox brand single-pane sealed glass-front gas fireplaces. The lawsuit claims that Lennox Industries Inc., Lennox Hearth Products Inc. and Lennox International Inc. ("Defendants") concealed that the glass fronts of these fireplaces get hot enough to cause serious burns. Defendants deny that they did not warn consumers and they deny they did anything wrong.

Who's Included?

Generally, with some exceptions, you are included if you live in the U.S. (including California) and own a home you bought for personal, family or household purposes that has one or more Superior or Lennox brand single-pane glass front gas fireplaces installed between February 6, 2004 and January 11, 2011. California residents who own a home for personal, family, or household purposes that has one or more Superior brand single-pane glass front gas fireplaces installed between March 1, 2003, and February 5, 2004, are also included.

What Can You Get?

If you qualify, you can get a protective screen for your Superior or Lennox brand gas fireplace that will significantly reduce the risks of burns by preventing direct contact with the glass. The Settlement also provides additional information regarding the safety of your fireplace, as well as a warning sticker to be placed on your fireplace control.

How to Get Benefits?

You must submit a Claim Form to get benefits. You can submit a Claim Form online or by mail. Claim forms are due by **August 1, 2011** or 60 days after the final approval hearing, whichever comes later.

Your Other Rights

If you do nothing, your rights will be affected. If you do not want to be legally bound by the Settlement, you must exclude yourself from the Settlement. The deadline to exclude yourself is **May 2, 2011**. If you do not exclude yourself you will not be able to sue the Defendants for any claim relating to the lawsuit. If you stay in the Settlement, you may object to it by **May 2, 2011**. The Court will hold a hearing on **June 2, 2011** to consider whether to approve the Settlement and a request for attorneys' fees up to \$4,750,000 and expenses up to \$180,000. The Court has appointed attorneys to represent the Class. If you wish, you or your own attorney may ask to appear and speak at the hearing at your own cost.

Call: 1-877-896-4837

Visit: www.LennoxHearthClass.com

Text "Lennox" to 41513 (Text messaging rates may apply)



Smoothing the Way The rock face of the formation known as the Rodadero takes a treatment from local Quechua people in April 1941. Across a field from the famed Inca fortress of Sacsahuamán, the undulating diorite slope has been smoothed more by time and its geology than by humans. Yet today tourists visiting the site overlooking Cusco, Peru, continue to buff the steep stone—with their backsides. The Rodadero makes a natural slide. —Margaret G. Zackowitz

👉 **Flashback Archive** Find all the photos at ngm.com.

PHOTO: THREE LIONS/NATIONAL GEOGRAPHIC STOCK

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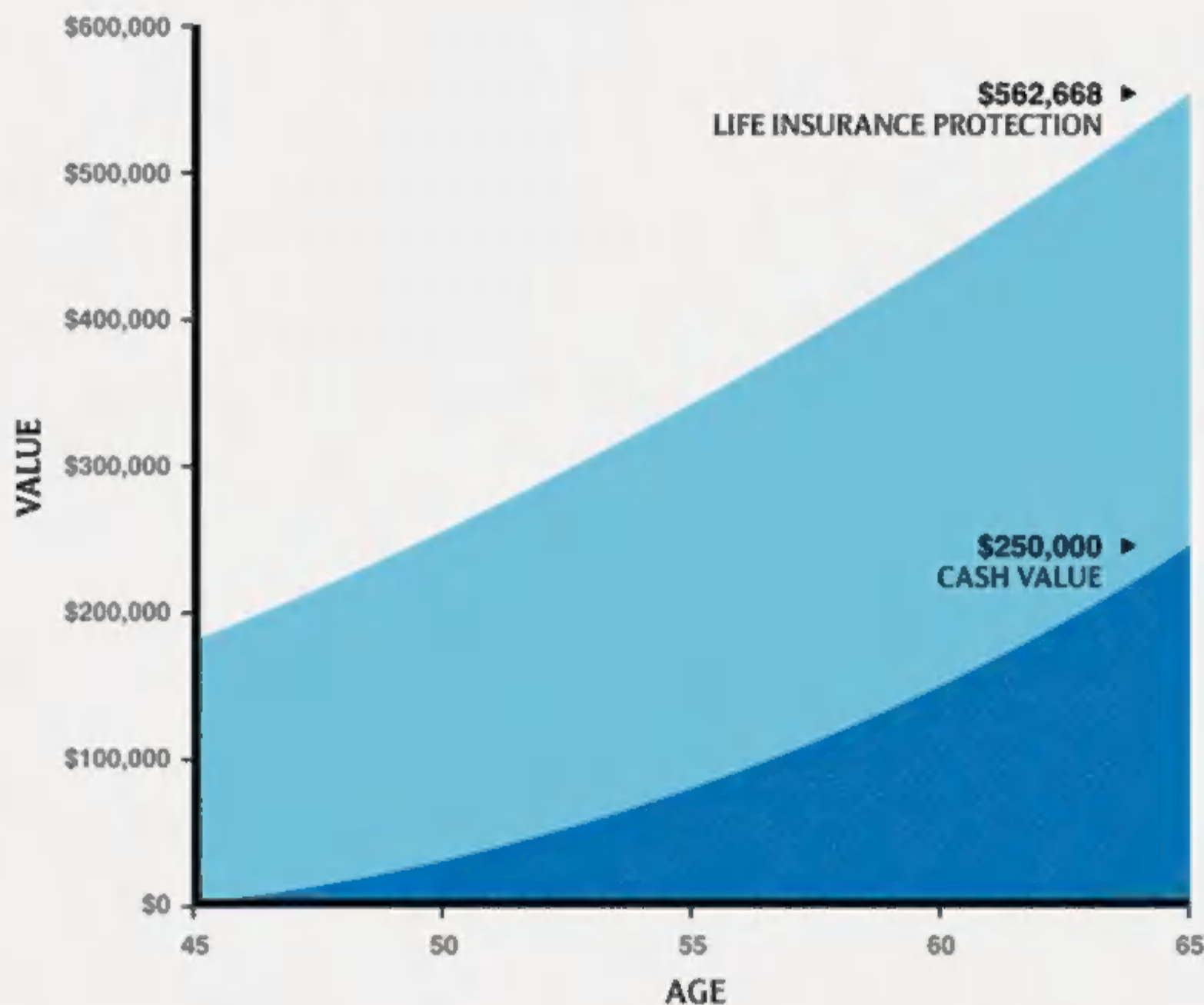


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*These figures represent the guaranteed cash value and guaranteed life insurance benefit of both the base policy and the PUAI purchased by an annual \$3,977.21 out-of-pocket payment. Guaranteed cash value begins accumulating at the end of the first policy year. Guarantees are backed by the claims-paying ability of New York Life Insurance Company. In Oregon, the Whole Life policy form number is 208.50.27. The form number for the OPP Rider is 208-330, which is a general form number and not specific to the state of Oregon.